



# eriphyton-Based Stormwater Treatment Area (PSTA) Research and Demonstration Project Phase 3 Interim Report No. 1 (August 2001 - October 2001)

*Prepared for*



**South Florida Water Management District**

*Prepared by*

**CH2MHILL**

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3301 Gun Club Road  
West Palm Beach, FL 33416

Subject: Phase 3 Interim Report No. 1 on the PSTA Research and Demonstration Project  
(C-E8624)

Dear Lori:

We are enclosing ten (10) copies of the referenced document along with an additional camera-ready copy that the District can use to make internal copies should the need arise. This report provides an interim summary of the data collected from the PSTA Field Scale Cells during the study period of August 2001 to October 2001. A more detailed data analysis will be presented in the Phase 3 final report.

Copies of the full document are being sent to the following interested parties: Frank Nearhoof and Taufiqal Aziz at the Florida Department of Environmental Protection, Nick Aumen at the National Park Service, Ron Jones at FIU (c/o Evelyn Gaiser), Bob Kadlec and Bill Walker. These additional copies will be shipped no later than tomorrow.

As always, should any questions arise regarding the enclosures, please feel free to call.

Sincerely,

CH2M HILL

Ellen Patterson  
Associate Scientist

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c: Jana Newman/SFWMD  
Bob Knight/WSI  
Jim Bays/CH2M HILL  
Steve Gong/CH2M HILL

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# Acronyms

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$\mu\text{g/L}$	micrograms per liter
$\mu\text{mhos/cm}$	microhoms per centimeter
$^{\circ}\text{C}$	degrees Celsius
cm	centimeter
cm/d	centimeters per day
CR	community respiration
DO	dissolved oxygen
in/day	inches per day
EAA	Everglades Agricultural Area
EFA	Everglades Forever Act
ENR	Everglades Nutrient Removal
EPCO	Equilibrium P concentration at zero P
ET	evapotranspiration
ft	feet
g	gram
g/m/y	grams per square meter per year
g/m <sup>2</sup>	grams per square meter
GPP	grow primary productivity
L/kg	liters per kilogram
m/y	meters per year
m <sup>2</sup>	square meter
m <sup>2</sup> /d	square meter per day
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MJ	megajoules
O <sub>2</sub> /m <sup>2</sup> /d	O <sub>2</sub> per square meter per day
P	phosphorus
PAR	photosynthetically active radiation
POR	period of record
ppb	parts per billion
PSTA	periphyton-based stormwater treatment area

SFWMD	South Florida Water Management District
STA	stormwater treatment areas
TDS	total dissolved solids
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TSS	total suspended solids

# Executive Summary

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The South Florida Water Management District (District) is conducting research focused on determining the effectiveness and design criteria of potential advanced treatment technologies to support the reduction of phosphorus (P) loads in surface waters entering the Everglades (SFWMD, 2000). Periphyton-based stormwater treatment areas (PSTAs) are one of the advanced treatment technologies being researched by the District for potential application downstream of the macrophyte-based stormwater treatment areas (STAs). Evaluations remain focused on PSTAs as post-STA treatment units intended to help achieve compliance with the ultimate total phosphorus (TP) criterion of 10 parts per billion (ppb).

A two-phased approach was originally adopted to investigate the PSTA concept. The project approach has been modified to include Phase 3, which includes a demonstration of PSTA viability, effectiveness, and sustainability at a larger field-scale. These three phases are highlighted below:

- **Phase 1** began in the spring of 1999 and ended in March 2000. Work included development of the work plan and experimental design, initial research in three experimental test cells (PSTA Test Cells) located at the southern end of the former Everglades Nutrient Removal (ENR) project (now part of STA-1W), and construction and research using 24 portable experimental mesocosms (Porta-PSTAs). Information collected during this project phase was summarized in the *Phase 1 Summary Report* (CH2M HILL, August 2000).
- **Phase 2** included the continued monitoring of the PSTA Test Cells and in Porta-PSTA mesocosms operated during Phase 1. Phase 2 research in the Porta-PSTAs concluded in early October 2000. Work in the PSTA Test Cells ended in March 2001 supplemental mass balance (destructive) sampling of selected Porta-PSTA mesocosms was conducted in February 2001, with results reported in the *Porta-PSTA Mass Balance (Destructive) Report* (CH2M HILL, August 2001). In addition, the expanded PSTA operational database was used to further refine and calibrate the performance forecast model, and develop design criteria for a full-scale PSTA system. The forecast model was applied to support projections of the long-term cost of implementing PSTAs to meet ultimate P reduction goals under the Everglades Forever Act (EFA). Information collected during this project phase was presented in the *Draft Phase 1 and 2 Summary Report* (CH2M HILL, October 2001), and in the *Draft Analyses Report* (CH2M HILL November 2001).
- **Phase 3** includes operation and monitoring of four 5-acre Field-Scale PSTA Cells located immediately west of STA-2. This demonstration phase is developing pilot-scale treatment system related to various methods of substrate preparation (limerock cap, scrape-down, and existing peat-based soils), effects of cell configuration and flow velocity, and effects of groundwater exchanges (losses and gains). In addition, a study of soil pretreatment options and effectiveness will be conducted during Phase 3. Field-Scale Cell construction was completed in early 2001 and monitoring began in late July 2001. The operations and monitoring schedule for the Field-Scale Demonstration Project has been extended through December 2002.

This report provides an interim summary of PSTA Field-Scale Cell data collected during the first 3 months of Phase 3 (August–October 2001). A more detailed analysis of PSTA Field-Scale data will be presented in the final Phase 3 report. Interim Phase 3 findings for the PSTA Field-Scale Cells for the study period are summarized as follows:

- Total incoming solar radiation averaged 12.87 megajoules (MJ) per square meter per day ( $\text{m}^2/\text{day}$ ) and photosynthetically active radiation (PAR) averaged 18.90 mols per  $\text{m}^2/\text{d}$ .
- The total rainfall was 48.8 cm (19.2 in), which is equal to approximately 0.80 centimeters per day ( $\text{cm}/\text{d}$ ) (0.32 inches per day [ $\text{in}/\text{d}$ ]), while evapotranspiration (ET) was 23.2 cm (9.14 in), or 0.38  $\text{cm}/\text{d}$  (0.15  $\text{in}/\text{d}$ ). These data indicate that there was a relatively large net rainfall input to the PSTA Field-Scale Cells (0.43  $\text{cm}/\text{d}$  or 0.17  $\text{in}/\text{d}$ ) during this research period.
- Leakance was estimated by measuring the change in static water levels during periods of no inflow pumping. Based on these estimates, net leakance rates appear to have declined in some cells between the construction and operation periods, with estimated leakance rates for the POR ranging from 2.2 to 4.0  $\text{cm}/\text{d}$ .
- Average inflow hydraulic loading rates estimated for this period for Cells 1 through 4 were 6.5, 11.4, 12.2, and 4.4  $\text{cm}/\text{d}$ , respectively. The average residuals (estimate for net groundwater exchanges) for Cells 1 through 4 for this same period were 4.6, 7.1, 3.2, and 4.0  $\text{cm}/\text{d}$ , respectively. These independent estimates of infiltration are comparable to those estimated by falling head leakance tests.
- Initial soil testing was conducted in the PSTA Field-Scale Cells. Results showed that percent moisture in the limerock cells averaged about 30 percent. TP averaged 105 milligrams per kilogram ( $\text{mg}/\text{kg}$ ) with about 72 percent in the inorganic form. Of the inorganic P, about 92 percent was calcium bound. Of the TP, about 67 percent was in the calcium bound form and 23 percent was in residual organic forms.
- The average TP in the inflow was 18 micrograms per liter ( $\mu\text{g}/\text{L}$ ) during this period. Of this TP, 8  $\mu\text{g}/\text{L}$  (44 percent) was in the dissolved form with about half as soluble reactive and half as dissolved organic P. Outflow TP averaged 13, 15, and 18  $\mu\text{g}/\text{L}$  in Cells 3, 2, and 1, respectively and 32  $\mu\text{g}/\text{L}$  in Cell 4.
- Average TP in all wells was 14  $\mu\text{g}/\text{L}$ , ranging from 10 to 23  $\mu\text{g}/\text{L}$ . The well located on the Cell 4 berm exhibited the highest average concentration of 21  $\mu\text{g}/\text{L}$ . The lowest average concentration of 10  $\mu\text{g}/\text{L}$  was observed at the well located near the outflow of Cell 3.
- Average periphyton dry weight biomass was highest in Cell 2 at 929 grams per square meter ( $\text{g}/\text{m}^2$ ) and lowest in Cell 3 at 368  $\text{g}/\text{m}^2$ . Average ash-free dry weight biomass in these cells ranged from 67 to 133  $\text{g}/\text{m}^2$ . Calcium made up a relatively small proportion of the ash weight in Cells 1 and 2 (10 to 12 percent) and was a higher proportion in Cell 3 (19 percent). Periphyton TP ranged from 0.08 to 0.23  $\text{g}/\text{m}^2$  (240 to 480  $\text{mg}/\text{kg}$ ) and was about 0.15 percent of the ash free dry weight in Cells 1, 0.17 percent in Cell 2, and 0.12 percent in Cell 3 periphyton. There are no periphyton data for Cell 4 during this study period because of operational difficulties.

- Algal biovolume was highest in Cell 2 and lowest in Cell 3. On a biovolume basis, blue green algal species dominated Cell 1 periphyton, green algal species dominated Cell 2 periphyton, and diatoms dominated the algal flora in Cell 3.
- A detailed periphyton P fractionation analyses showed that TP ranged from 240 to 480 mg/kg, with approximately 60 percent in the organic form. Of this organic TP, about 37 percent was recalcitrant.
- Dominant macrophyte species included the macroalga *Chara*, spikerush (*Eleocharis cellulosa*), and narrow-leaf cattail (*Typha latifolia*). Average above-ground, dry-weight macrophyte biomass ranged from a low of 19.2 g/m<sup>2</sup> in Cell 3 to a high of 182 g/m<sup>2</sup> in Cell 1 because of operational difficulties. There were no macrophyte biomass estimates from Cell 4 during this POR.
- Average gross primary productivity (GPP) ranged from 2.3 grams (g) of O<sub>2</sub> per square meter per day (O<sub>2</sub>/m<sup>2</sup>/d) in Cell 3 to 4.1 g of O<sub>2</sub>/m<sup>2</sup>/d in Cell 2. Community respiration (CR) ranged from 2.4 g of O<sub>2</sub>/m<sup>2</sup>/d in Cell 3 to 4.0 g of O<sub>2</sub>/m<sup>2</sup>/d in Cell 2. The average ratio between GPP and CR in these cells was slightly higher than 1 in Cells 1 and 2 and less than 1 in Cell 3. There was a very small amount of net productivity estimated for Cells 1 and 2 and a negative net production estimated in Cell 3.

## SECTION 1

# Project Background

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## 1.1 Introduction

The South Florida Water Management District (District) is conducting research focused on determining the effectiveness and design criteria of potential advanced treatment technologies to support the reduction of phosphorus (P) loads in surface waters entering the remaining Everglades (SFWMD, 2000). Particular focus is being placed on the treatment of surface waters from the Everglades Agricultural Area (EAA) as well as Lake Okeechobee water that is diverted through the primary canal system to the Lower East Coast of Florida.

Periphyton-based stormwater treatment areas (PSTAs) are one of the advanced treatment technologies being researched by the District for potential application downstream of the macrophyte-based stormwater treatment areas (STAs). Evaluations remain focused on PSTAs as post-STA treatment units intended to help achieve compliance with the anticipated ultimate total phosphorus (TP) criterion of 10 parts per billion (ppb).

In concept, the periphyton complex is hypothesized as being capable of extracting available P in the water introduced into the system and incorporation of that P into the biomass of the periphyton mat. Settling of detrital matter contributes to the long-term P storage. Additionally, because of the high primary productivity of these periphyton systems, water quality conditions favor P precipitation and binding into the newly formed sediments. The result is a water outflow with much of the available P scavenged and retained in the system biomass and sediments. These concepts are depicted in Exhibit 1-1.

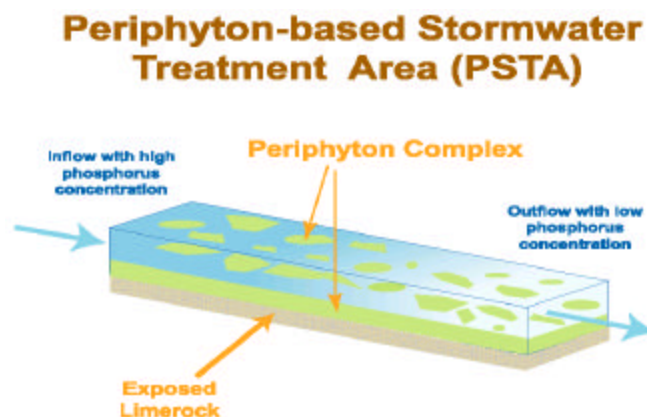


EXHIBIT 1-1

Schematic Diagram of the Periphyton Stormwater Treatment Area (PSTA) Concept

Prior to initiation of the District's PSTA project in July 1998, detailed research to evaluate PSTA feasibility had not been performed. The key study objectives, therefore, were to research and demonstrate (to the extent possible within the contract period) PSTA viability, effectiveness, and sustainability at several scales of application. The following specific questions were to be addressed:

- Viability: Can periphyton-dominated ecosystems for P control be established?
- Effectiveness: Can P removal and retention be achieved?
- Sustainability: Can PSTA viability and effectiveness be maintained for long-term periods?

Viability was assessed by documenting how long it took for the development of periphyton-dominated plant communities in the PSTA mesocosms, and whether they could be maintained for reasonable periods of time. Effectiveness as a water quality treatment approach was evaluated based on the ability of the PSTA test systems to achieve low TP outflow concentrations. The TP removal rate constant, a metric for phosphorus removal efficiency, was quantified for the various PSTA mesocosm conditions tested during the study. Because sustainability issues would not be fully addressable within the anticipated 3-year study period, this question was evaluated through development and application of a performance forecast model based on the empirical data generated by the field studies.

A two-phased approach was originally adopted to investigate the PSTA concept: an Experimental Phase (Phase 1), and a Validation/Optimization Phase (Phase 2). The project approach has been modified to include Phase 3, which includes a demonstration of PSTA viability, effectiveness, and sustainability at a larger Field-Scale Cell. The types of activities that are included in each phase are described as follows:

- Phase 1 included development of the work plan and experimental design, initial research in three experimental test cells (PSTA Test Cells) located at the southern end of the Everglades Nutrient Removal (ENR) project (see SFWMD 2000 for location of sites), and construction and startup/monitoring of research using 24 portable experimental mesocosms (Porta-PSTAs). The Phase 1 experimental studies provided critically needed information for addressing basic issues associated with PSTA viability and treatment performance effectiveness. Development of a preliminary forecast model and preliminary model calibration were also completed.
- Phase 2 included continuing research in the ENR PSTA Test Cells and in the Porta-PSTAs, and design and observations during the District's construction of the Field-Scale demonstration PSTAs immediately west of STA-2. During Phase 2, the expanded PSTA operational database was used to further refine and calibrate the performance forecast model, and develop design criteria for a full-scale PSTA system. The forecast model was applied to support projections of the long-term cost of implementing PSTAs to meet ultimate P reduction goals under the Everglades Forever Act (EFA).
- Phase 3 includes operation and monitoring of four 5-acre Field-Scale PSTA Cells located immediately west of STA-2. This demonstration phase is developing pilot scale treatment system performance data related to various methods of substrate preparation (limerock fill, scrape-down, and existing peat-based soils), effects of cell configuration

and flow velocity, effects of groundwater exchanges, and soil pretreatment options and effectiveness.

In the aggregate, the PSTA Research and Demonstration Project is designed to develop defensible conclusions related to specific hypotheses that are relevant to key research questions and design issues described in the PSTA Research Plan (CH2M HILL, 2001). This interim report provides a summary of the PSTA findings during the Phase 3 operational period of August to October 2001.

## 1.2 Experimental Design

This section provides some key information related to the experimental design used in Phase 3 of the PSTA project. Exhibit 1-2 provides a summary of the Field-Scale PSTA design criteria and treatments during Phase 3. A more detailed description of the Field-Scale PSTA demonstration site is provided below.

### 1.2.1 Field-Scale Design Criteria

Exhibit 1-3 schematically illustrates the PSTA Field-Scale Demonstration Facility layout. Four PSTA Cells were constructed between April 2000 and early 2001 from onsite materials. These four cells are each approximately 20,000 square meters (m<sup>2</sup>) (5 acres). Three of the cells are rectangular at 61 m wide by 317 m long (200 by 1,040 feet [ft]) and one cell is sinuous with a length of 951 m (3,120 ft) and a width of 21 m (70 ft). Cells 1 and 2 have approximately 60 centimeters (cm) or 24 inches of limrock placed over the native peat soils. The relatively shallow peat soils were excavated and removed from Cell 3 to expose the underlying caprock. Native peat soils with no amendments or other pre-treatments comprise the floor of Cell 4. Field-Scale construction activities and other key dates are summarized in Appendix A.

Influent water to this facility can be conveyed from two sources: the western STA-2 seepage control canal or Cell 3 of STA-2. These water sources can be used independently or by blending. Influent canal water is pumped through inlet manifolds into the four PSTA Cells using diesel pumps. The inlet flow rate is measured with an in-line magnetic meter in each inlet manifold. Water flows by gravity from the inlet deep zones to the outlet deep zones, which distribute and collect these flows. Water flows out of each cell through a single outlet weir box equipped with an AgriDrain water level control structure, which contains 60-cm-wide removable stoplogs. The top stoplog acts as a horizontal overflow weir and controls the water level in the cell as well as being used in conjunction with a water level recorder for outflow quantification. Scaffold-type "boardwalks" are installed across the width of each cell at the center point to allow access for internal sampling. A series of groundwater sampling wells are arranged within and around the PSTA Cells to allow monitoring of groundwater TP gains and losses. Low densities of spikerush were planted in bands across the width of each cell with the objective of helping to prevent periphyton mat wash out toward the outflow structure. Periphyton colonization was by natural recruitment. Construction of the PSTA Field-Scale Demonstration Facility was substantially completed during the first quarter of 2001, and routine operation and monitoring began in late July 2001. Start up of formal monitoring was delayed by the drought of 2001 and mechanical problems with the inflow pumps. The period-of-record (POR) covered in this interim report is August through October 2001.

**EXHIBIT 1-2**
**Summary of Experimental Treatments and Design Criteria for PSTA Field-Scale Demonstration Cells**

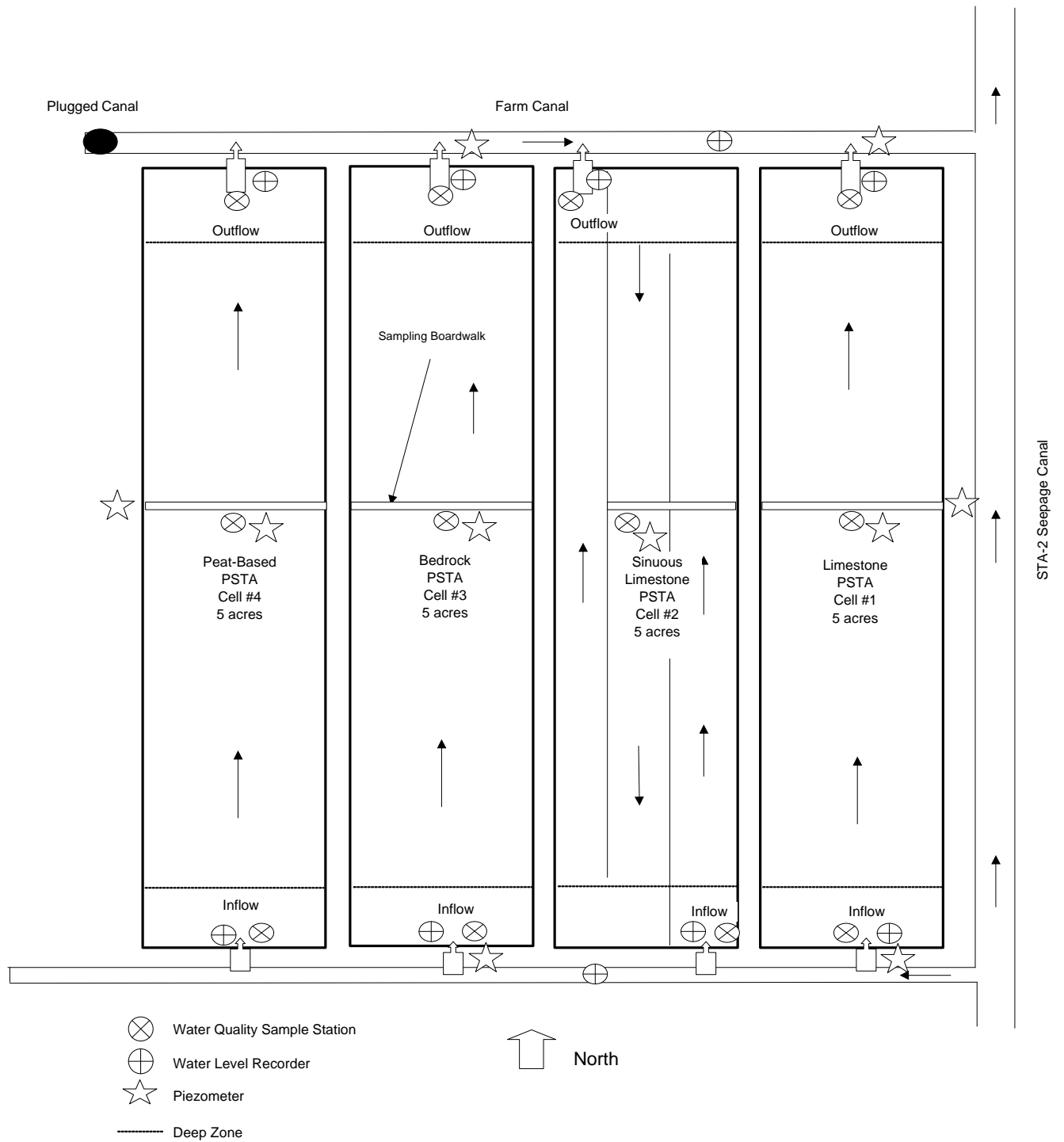
Design Parameter	Field-Scale PSTA Treatment			
	1	2	3	4
No. Cells	1	1	1	1
Flow (m <sup>3</sup> /d)				
Average	1,250	1,250	1,250	1,250
Maximum	2,500	2,500	2,500	2,500
Minimum	0	0	0	0
Cell Length (m)	315	945	315	315
Cell Width (m)	66	22	66	66
Aspect Ratio	5	43	5	5
Horizontal Cell Area (m <sup>2</sup> )	20,790	20,790	20,790	20,790
Operational Water Depth (m)				
Average	0.30	0.30	0.30	0.30
Maximum	0.60	0.60	0.60	0.60
Minimum	0.00	0.00	0.00	0.00
Operational Water Volume (m <sup>3</sup> )				
Average	6,237	6,237	6,237	6,237
Maximum	12,474	12,474	12,474	12,474
Minimum	0	0	0	0
Nominal Hydraulic Residence Time (d)				
@ average flow and depth	5.0	5.0	5.0	5.0
@ maximum flow and minimum depth	0.0	0.0	0.0	0.0
@ minimum flow and maximum depth	INF	INF	INF	INF
Hydraulic Loading Rate (cm/d)				
@ average flow and depth	6.0	6.0	6.0	6.0
@ maximum flow	12.0	12.0	12.0	12.0
@ minimum flow	0.0	0.0	0.0	0.0
Nominal Linear Velocity (m/d)				
@ average flow and depth	63	189	63	63
Substrate	LR-PE	LR-PE	CR	PE
Liner (Yes/No)	No	No	No	No
Deep Zones				
Number per Cell	2	4	2	2
Depth Below Floor Elevation (m)	1	1	1	1
Plant Species (Yes/No)				
Periphyton	Yes	Yes	Yes	Yes
Macrophytes	Yes	Yes	Yes	Yes
Design TP Influent Quality (µg/L)				
Average	25	25	25	25
Maximum	40	40	40	40
Minimum	15	15	15	15
Design TP Mass Loading (g/m <sup>2</sup> /y)				
Average	0.55	0.55	0.55	0.55
Maximum	0.88	0.88	0.88	0.88
Minimum	0.33	0.33	0.33	0.33

PE = peat

LR-PE = limerock fill over peat

CR = limestone caprock

INF = infinite



**EXHIBIT 1-3**  
Schematic of Field-Scale Cells Showing Sampling Locations

## 1.2.2 Sampling Plan

Exhibit 1-4 summarizes the analytical sampling plan for the Field-Scale PSTA Demonstration Project. Water stage and flows in the cells are continuously monitored. Field measurements are collected weekly, as are inflow and outflow P forms. Other important water quality parameters, such as nitrogen and calcium, are monitored monthly. Biological sampling for periphyton and macrophyte biomass and P storages is conducted monthly or quarterly. Sediments were sampled at the start of Phase 3 and will be sampled again at the midpoint and end of the monitoring period. The operations and monitoring schedule for the Field-Scale Demonstration Project has been extended through December 2002. The scope of these efforts is discussed further in Section 7.

## 1.3 Document Organization

This interim report summarizing PSTA findings during the Phase 3 operational period of August to October 2001 consists of the following sections:

Section 1: Introduction

Section 2: Environmental Forcing Functions

Section 3: Site Hydrology and Water Balance

Section 4: Antecedent Soils

Section 5: Water Quality

Section 6: Biological Community

Section 7: Continuing Operations Plan

Section 8: Works Cited

Appendix A: Key Dates Summary

Appendix B: Trend Charts

Appendix C: Detailed Algal Species Counts and Biovolumes

**EXHIBIT 1-4**

## Field-Scale Cell Monitoring Parameters and Frequency

Parameter	Sampling Locations and Frequency					
	Piezometers	Inflow Canal	Inflow	1/2	Outflow	Outflow Canal
<b>Field Meter Readings</b>						
Flow	NA	NA	Pump	NA	calc	NA
Water Stage	W	C(I)	W	C(I)	W	C(I)
Water temperature	M	W	W	C(I)	W	NA
Dissolved oxygen	NA	W	W	C(I)	W	NA
pH	M	W	W	C(I)	W	NA
Conductivity	M	W	W	C(I)	W	NA
Total Dissolved Solids	M	W	W	C(I)	W	NA
Turbidity	M	W	W	C(I)	W	NA
PAR	NA	NA	NA	M	NA	NA
<b>Water Quality Analyses</b>						
Phosphorus (P) Series						
Total P	M	W	M	M	W	NS
Dissolved Reactive P	NS	W	M	M	W	NS
Total Dissolved P	NS	W	M	M	W	NS
Nitrogen Series						
Total N	NS	NS	M	M	M	NS
Ammonia N	NS	NS	M	M	M	NS
TKN	NS	NS	M	M	M	NS
Nitrate+nitrite N	NS	NS	M	M	M	NS
Total Suspended Solids	NS	NS	M	M	M	NS
Total Organic carbon	NS	NS	M	M	M	NS
Calcium	NS	NS	M	M	M	NS
Alkalinity	NS	NS	M	M	M	NS
Chlorides	M	NS	M	M	M	NS
<b>Biological Analyses</b>						
Periphyton Cover	NS	NS	NS	M	NS	NS
Macrophyte Cover	NS	NS	NS	M	NS	NS
Periphyton Dominant Species	NS	NS	NS	Q (a)	NS	NS
Biomass (AFDW)	NS	NS	NS	Q (a)	NS	NS
Calcium	NS	NS	NS	Q (a)	NS	NS
Chlorophyll a, b, c, phaeophytin	NS	NS	NS	Q (a)	NS	NS
Phosphorus (P) Series						
Total P	NS	NS	NS	Q (a)	NS	NS
Total Inorganic P	NS	NS	NS	Q (a)	NS	NS
Non-reactive P (fractionation)	NS	NS	NS	Q (a)	NS	NS
TKN	NS	NS	NS	Q (a)	NS	NS
Accretion (Net Organic/Inorganic)	NS	NS	NS	Q (a)	NS	NS
<b>Sediments (Start and End)</b>						
Phosphorus (P) Series						
Total P	NS	NS	NS	S/M/E	NS	NS
Total Inorganic P	NS	NS	NS	S/M/E	NS	NS
Non-reactive P (fractionation)	NS	NS	NS	S/M/E	NS	NS
Phosphorus Sorption/Desorption	NS	NS		S/M/E		NS
Total Kjeldahl N	NS	NS	NS	S/M/E	NS	NS
Total Organic Carbon	NS	NS	NS	S/M/E	NS	NS
Bulk density	NS	NS	NS	S/M/E	NS	NS
Solids (percent)	NS	NS	NS	S/M/E	NS	NS
<b>System-Level Parameters</b>						
Gross primary productivity	NS	NS		C(I)		NS
Net primary productivity	NS	NS		C(I)		NS
Community respiration	NS	NS		C(I)		NS

**Notes:**

(a) Three replicate samples taken along the boardwalk of each cell.

W = weekly

M = monthly

Q = quarterly

(D) = sampled by District

C(I) = continuous with instrument

NS = not sampled

S/M/E = start, mid-point and end of study phase

NA = not applicable

## SECTION 2

# Environmental Forcing Functions

## 2.1 Introduction

External environmental forcing functions that have affected the growth and performance of the pilot-scale PSTAs include:

- Temperature
- Solar inputs (measured as total insolation and photosynthetically active radiation [PAR])
- Rain inputs
- Evapotranspiration (ET) outputs
- Inflows and associated P concentrations (described in Section 3)

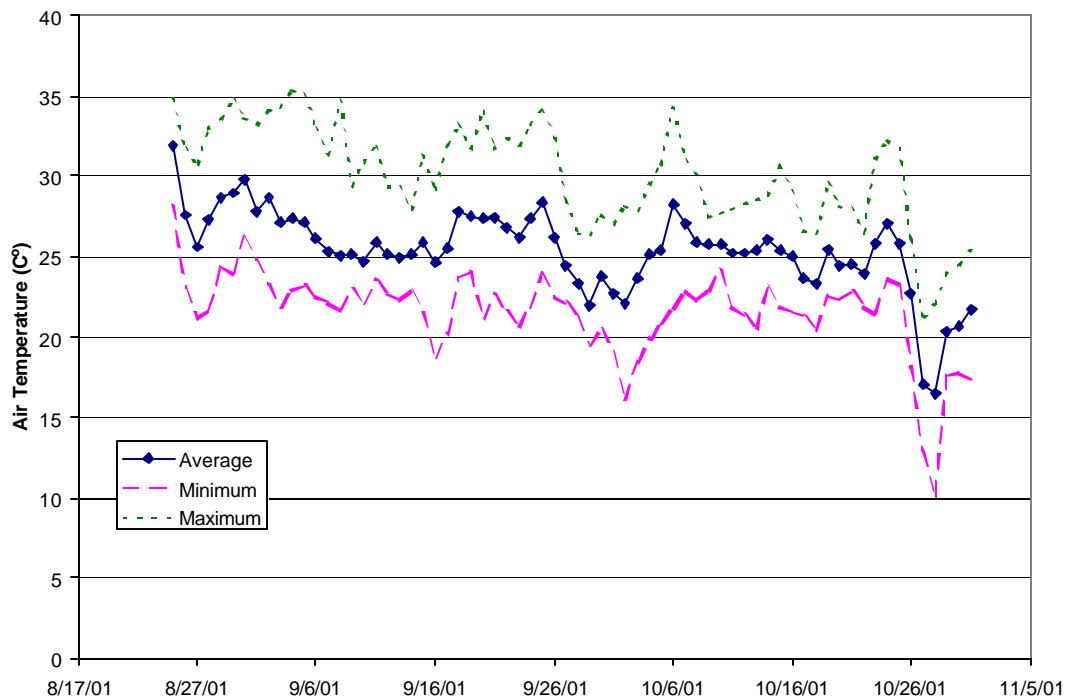
The general history of each of the first four of these forcing functions for the Phase 3 POR is presented below.

## 2.2 Temperature

Air temperature affects the rates of all chemical and biological reactions. Exhibit 2-1 presents a summary of the daily mean, maximum, and minimum air temperatures recorded at the Field-Scale site during this operational period.

### EXHIBIT 2-1

Average Daily Air Temperature Data from the Field-Scale PSTA Project Site



## 2.3 Solar Inputs

Exhibit 2-2 summarizes the total insolation and PAR received at the project site during the Phase 3 POR. During this period, total insolation averaged 12.87 megajoules (MJ) per m<sup>2</sup>/day (d) and PAR averaged 18.90 mols per m<sup>2</sup>/d.

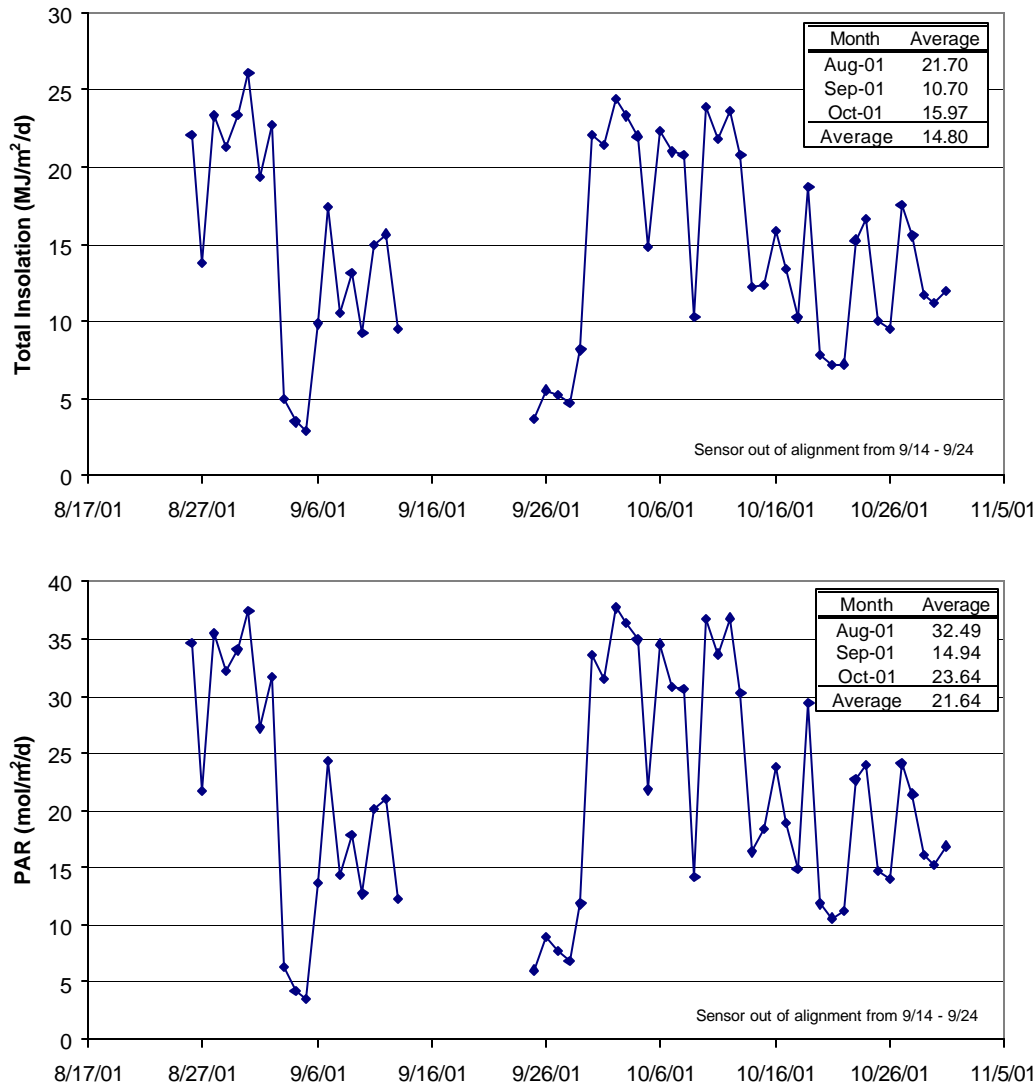
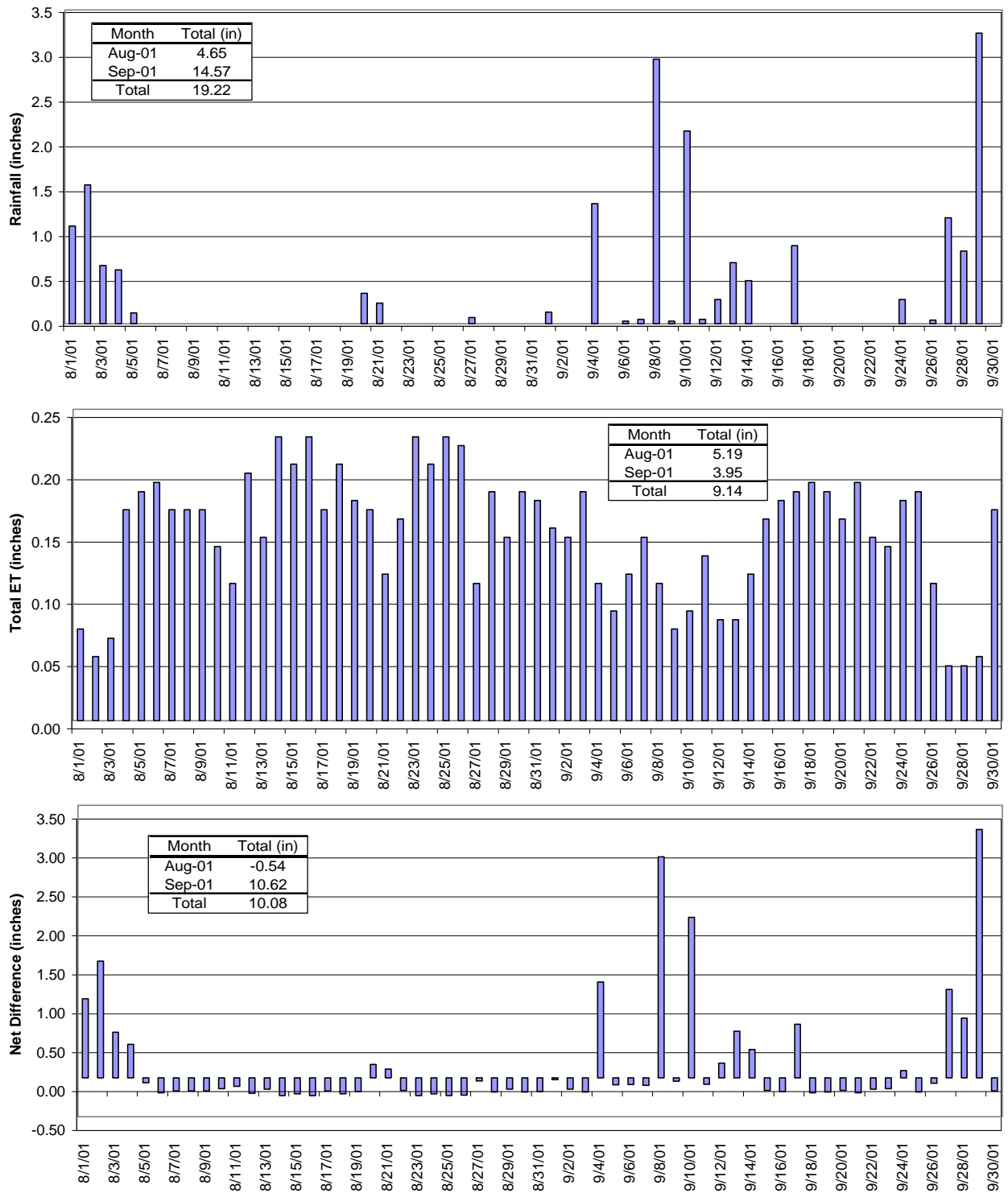


EXHIBIT 2-2

Total Solar Radiation and Photosynthetically Active Radiation (PAR) Measured at the Field-Scale PSTA Project Site

## 2.4 Precipitation and Evapotranspiration

Exhibit 2-3 compares the measured rainfall and estimated ET and their net difference during this POR. Daily rainfall and ET for October 2001 were not yet available from the District at the time of this report. The total rainfall for the August and September period was 48.8 cm (19.2 in), which is equal to approximately 0.80 cm/d (0.32 in/d), while ET was 23.2 cm (9.14 in), or 0.38 cm/d (0.15 in/d). These data indicate that there was a relatively large net rainfall input to the PSTA Field-Scale Cells (0.43 cm/d or 0.17 in/d) during this research period.



**EXHIBIT 2-3**  
Daily Rainfall and Evapotranspiration Data at the District Rainfall (S7\_R) and Evapotranspiration (STA1W) Stations

## SECTION 3

# Site Hydrology and Water Balance

---

## 3.1 Introduction

One key research issue in the Field-Scale PSTA project is related to quantifying the effects of leakance to and from the groundwater. Previous work conducted in the Porta-PSTAs and PSTA Test Cells did not have groundwater exchanges since it was conducted in fiberglass tanks and lined constructed wetland cells. In contrast, the Field-Scale PSTA Cells are unlined constructed wetlands that clearly will be affected by groundwater conditions in a manner similar to that for the existing STAs or for prospective full-scale PSTA systems. While inflows are intended to be relatively constant, they have varied considerably during the first operational quarter due to pump problems and continuing construction and operational needs. Other water gains and losses are also irregular. Rainfall is intermittent; evapotranspiration follows a daily rhythm affected by time of day, cloud cover, wind, and temperature; and groundwater seepage responds to water depth inside and outside the cells as well as to changing soil conditions. Outflows from the cells are equal to the sum of these water inputs and outputs. Monitoring efforts to-date have focused on quantifying the magnitude of these various water flows. A preliminary water balance and estimates of leakance are provided below for the PSTA Field-Scale Cells.

Components of the water balance that are directly measured or estimated on-site include surface water inflows and outflows, and rainfall. Inflows were not monitored until November 8, 2001, when magmeters were installed on all four inflow manifolds. Prior to November 8, inflows were estimated based on water level records, which indicated when the pumps were running and the average pumping rate from the November period when inflows were directly measured. Outflows are estimated through use of a recording water level sensor and a weir equation for flow over a 24-inch horizontal weir with end constrictions. Evapotranspiration is estimated from a District station located in STA-1W. Storage is estimated from beginning and ending water level records in the cells. Groundwater exchanges are calculated by difference and compared to the results of cell-wide leakance estimates.

## 3.2 Leakance Assessment

Exhibit 3-1 summarizes average net leakance rates during the construction period prior to August 2001, and during routine operation in August and September 2001. Leakance was estimated by measuring the change in static water levels in the cells during periods of no inflow pumping. Based on the estimates in Exhibit 3-1, net leakance rates appear to have declined between the construction and operation periods. Additional leakance assessments will be conducted periodically during the rest of this project phase.

### EXHIBIT 3-1

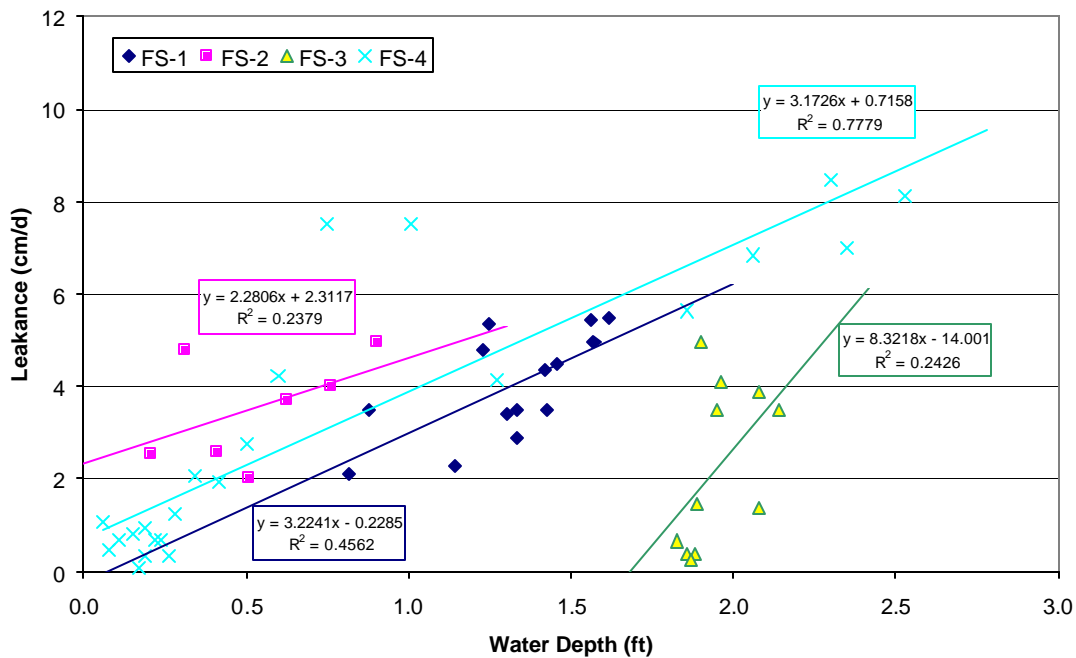
Estimated Leakance Rates (cm/d) for the Field-Scale PSTA Cells

PSTA Cell	Initial Estimates	Following Leak Repairs	August - September 2001
FS-1	6.7	5.3	4.0
FS-2	10.7	7.8	3.5
FS-3	3.4	Note A	2.2
FS-4	Note B	Note B	3.2

Note A: Water levels in FSC-3 did not drop significantly for this period and thus leakance could not be estimated for this period.

Note B: The cell was not yet constructed at the time of the leakance analysis.

Exhibit 3-2 illustrates the observed relationship between water depth and leakance for each of the four Field-Scale Cells. Leakance is observed to increase with higher water depths in all of the cells.



### EXHIBIT 3-2

Observed Relationship Between Water Depth and Leakance Rates for the Field-Scale PSTA Cells

## 3.3 Water Budget

Exhibit 3-3 provides estimated weekly, monthly, and POR water balances for the Field-Scale PSTA Cells. All surface water inflows are estimated values. Average inflow hydraulic loading rates estimated for this period for Cells 1 through 4 were 6.5, 11.4, 12.2, and 4.4 cm/d, respectively. The residual term in Exhibit 3-3 is an independent estimate of net groundwater exchanges. The average residuals for Cells 1 through 4 for this same period were 4.6, 7.1, 3.2, and 4.0 cm/d, respectively. These independent estimates of infiltration are comparable to those estimated by falling head leakance tests.

**EXHIBIT 3-3**

Estimated Water Balance for the Field-Scale PSTA Cells, August to October 2001

Cell	Frequency	Time Period	Rainfall		Evapotranspiration		Inflow <sup>a</sup>		Outflow		Chng Storage (m <sup>3</sup> )	Residual		
			(in)	(m <sup>3</sup> )	(mm)	(m <sup>3</sup> )	(m <sup>3</sup> /d)	(m <sup>3</sup> )	(m <sup>3</sup> /d)	(m <sup>3</sup> )		(m <sup>3</sup> )	(% of Inflow)	(cm/d)
FSC-1	Weekly	07/29/2001	4	1,999	9	185	2,530	17,710	---	---	---	---	---	---
		08/05/2001	0	62	29	582	1,084	7,590	2,018	14,123	-11,733	4,679	61.2	3.3
		08/12/2001	0	0	35	711	1,084	7,590	0	0	5,859	1,020	13.4	0.7
		08/19/2001	1	293	33	662	1,807	12,650	86	600	4,626	7,056	54.5	5.0
		08/26/2001	0	103	30	605	2,530	17,710	1,082	7,571	-221	9,858	55.3	7.0
		09/02/2001	4	2,246	23	465	723	5,060	202	1,411	-2,436	7,867	107.7	5.6
		09/09/2001	4	1,881	19	378	1,446	10,120	275	1,927	298	9,398	78.3	6.6
		09/16/2001	1	447	31	635	1,084	7,590	46	323	2,210	4,869	60.6	3.4
		09/23/2001	6	2,847	19	386	361	2,530	73	511	-2,251	6,732	125.2	4.8
		09/30/2001	0	0	4	87	1,084	7,590	290	2,032	2,714	2,757	36.3	1.9
		10/07/2001	---	---	---	---	1,446	10,120	680	4,757	-2,935	---	---	---
		10/14/2001	---	---	---	---	1,446	10,120	266	1,863	2,755	---	---	---
		10/21/2001	---	---	---	---	1,807	12,650	1,134	7,941	-1,429	---	---	---
		10/28/2001	---	---	---	---	0	0	0	0	-2,457	---	---	---
FSC-2	Weekly	07/29/2001	4	1,999	9	185	3,373	23,611	---	---	---	---	---	---
		08/05/2001	0	62	29	582	1,446	10,119	0	0	-5,801	15,400	151.3	10.9
		08/12/2001	0	0	35	711	0	0	0	0	-1,022	311	---	0.2
		08/19/2001	1	293	33	662	482	3,373	0	0	334	2,670	72.8	1.9
		08/26/2001	0	103	30	605	2,891	20,238	17	121	20,003	-388	-1.9	-0.3
		09/02/2001	4	2,246	23	465	964	6,746	245	1,714	-2,256	9,069	100.9	6.4
		09/09/2001	4	1,881	19	378	2,409	16,865	0	0	-1,208	19,576	104.4	13.8
		09/16/2001	1	447	31	635	1,446	10,119	445	3,118	4,672	2,141	20.3	1.5
		09/23/2001	6	2,847	19	386	3,373	23,611	2,299	16,096	36	9,941	37.6	7.0
		09/30/2001	0	0	4	87	3,373	23,611	2,153	15,069	-123	8,578	36.3	6.1
		10/07/2001	---	---	---	---	3,373	23,611	1,888	13,218	-766	---	---	---
		10/14/2001	---	---	---	---	3,373	23,611	1,590	11,132	524	---	---	---
		10/21/2001	---	---	---	---	3,373	23,611	2,062	14,431	-987	---	---	---
		10/28/2001	---	---	---	---	3,373	23,611	731	5,117	704	---	---	---
FSC-3	Weekly	07/29/2001	4	1,999	9	185	3,121	21,847	---	---	---	---	---	---
		08/05/2001	0	62	29	582	1,338	9,363	3,063	21,443	-7,807	-4,794	-50.9	-3.4
		08/12/2001	0	0	35	711	1,338	9,363	0	0	925	7,727	82.5	5.5
		08/19/2001	1	293	33	662	3,121	21,847	610	4,269	5,895	11,314	51.1	8.0
		08/26/2001	0	103	30	605	3,121	21,847	2,450	17,148	-905	5,101	23.2	3.6
		09/02/2001	4	2,246	23	465	3,121	21,847	254	1,780	-869	22,716	94.3	16.0
		09/09/2001	4	1,881	19	378	3,121	21,847	2,725	19,076	1,650	2,624	11.1	1.9
		09/16/2001	1	447	31	635	1,338	9,363	1,915	13,407	-2,395	-1,837	-18.7	-1.3
		09/23/2001	6	2,847	19	386	2,675	18,726	2,204	15,426	2,595	3,166	14.7	2.2
		09/30/2001	0	0	4	87	1,338	9,363	2,892	20,247	-2,452	-8,520	-91.0	-6.0
		10/07/2001	---	---	---	---	2,229	15,605	2,648	18,535	2,210	---	---	---
		10/14/2001	---	---	---	---	3,121	21,847	2,516	17,615	-843	---	---	---
		10/21/2001	---	---	---	---	3,121	21,847	1,243	8,701	463	---	---	---
		10/28/2001	---	---	---	---	3,121	21,847	2,925	20,477	725	---	---	---
FSC-4	Weekly	07/29/2001	4	1,999	9	185	1,839	12,873	---	---	---	---	---	---
		08/05/2001	0	62	29	582	263	1,839	0	0	-6,301	7,619	400.9	5.4
		08/12/2001	0	0	35	711	0	0	0	0	-2,272	1,561	---	1.1
		08/19/2001	1	293	33	662	263	1,839	0	0	540	931	43.7	0.7
		08/26/2001	0	103	30	605	0	0	0	0	57	-559	-543.8	-0.4
		09/02/2001	4	2,246	23	465	788	5,517	0	0	14,550	-7,252	-93.4	-5.1
		09/09/2001	4	1,881	19	378	1,051	7,356	0	0	-144	9,003	97.5	6.4
		09/16/2001	1	447	31	635	0	0	0	0	-4,384	4,196	938.4	3.0
		09/23/2001	6	2,847	19	386	1,576	11,034	0	0	4,934	8,562	61.7	6.0
		09/30/2001	0	0	4	87	1,839	12,873	0	0	-1,331	14,117	109.7	10.0
		10/07/2001	---	---	---	---	1,839	12,873	0	0	-966	---	---	---
		10/14/2001	---	---	---	---	1,314	9,195	0	0	-3,942	---	---	---
		10/21/2001	---	---	---	---	525	3,678	0	0	2,513	---	---	---
		10/28/2001	---	---	---	---	1,839	12,873	0	0	-380	---	---	---
FSC-1	Monthly	Aug-01	5	2,390	132	2,666	1,714	53,130	758	23,513	-1,732	31,073	56.0	5.0
		Sep-01	15	7,488	100	2,031	928	27,830	158	4,727	-2,734	31,294	88.6	5.2
		Oct-01	---	---	---	---	1,306	40,480	535	16,594	-786	---	---	---
FSC-2	Monthly	Aug-01	5	2,390	132	2,666	1,414	43,849	0	0	1,208	42,365	91.6	6.8
		Sep-01	15	7,488	100	2,031	2,136	64,087	777	23,300	1,753	44,492	62.2	7.3
		Oct-01	---	---	---	---	3,373	104,563	1,759	54,524	-401	---	---	---
FSC-3	Monthly	Aug-01	5	2,390	132	2,666	2,316	71,783	1,481	45,922	-2,215	27,800	37.5	4.4
		Sep-01	15	7,488	100	2,031	2,601	78,025	1,825	54,742	1,367	27,374	32.0	4.5
		Oct-01	---	---	---	---	2,517	78,025	2,356	73,028	-41	---	---	---
FSC-4	Monthly	Aug-01	5	2,390	132	2,666	356	11,034	0	0	-8,192	18,950	141.2	3.0
		Sep-01	15	7,488	100	2,031	858	25,746	0	0	14,992	16,212	48.8	2.7
		Oct-01	---	---	---	---	1,424	44,136	0	0	-3,037	---	---	---
FSC-1	POR	Aug - Oct 01	19	9,878	232	4,697	1,320	120,120	472	42,929	-2,112	84,485	65.0	4.6
FSC-2	POR	Aug - Oct 01	19	9,878	232	4,697	2,310	210,189	895	81,402	2,616	131,353	59.7	7.1
FSC-3	POR	Aug - Oct 01	19	9,878	232	4,697	2,476	225,357	1,911	173,930	-2,297	58,905	25.0	3.2
FSC-4	POR	Aug - Oct 01	19	9,878	232	4,697	880	80,036	0	0	11,749	73,469	81.7	4.0

<sup>a</sup> Estimated based on pumping runtimes

---Data pending from the District

## SECTION 4

# Antecedent Soils

---

## 4.1 Introduction

Phase 1 and 2 PSTA work indicated that antecedent soil properties affect community development and TP removal performance (CH2M HILL, 2001). One of the key goals of the Phase 3 demonstration work is to investigate these effects on a larger scale. Also, additional smaller scale experiments (see Section 7) have been added to the Phase 3 PSTA work to document the effects of a range of soil amendments on TP removal performance.

This section summarizes the results from initial soil testing in the PSTA Field-Scale Cells. Nine samples of soil were collected on February 8, 2001, at three evenly spaced locations across three transverse transects: inflow, center, and outflow. Cells 1 through 3 had been previously flooded prior to soil sampling. Cell 4 has not yet received any flood water at the time of sampling. Soil was composited by transect for laboratory analysis of the following parameters:

- Percent solids
- TP
- Total inorganic P
- Total organic P
- Residual P fractions

These three composites were then composited to provide a single cell sample for analysis of the following:

- Equilibrium P concentration at zero P ( $EPC_0$ )
- One-point sorption isotherm linear adsorption coefficient
- Initial adsorbed P at  $C = 0$

Finer soil material was sampled in the limerock and scrape-down cells. Data for each of these preliminary analyses are summarized below.

## 4.2 Results

Exhibit 4-1 summarizes the preliminary soil analyses from the Field-Scale PSTA Cells. These samples were collected on February 8, 2001. Percent moisture in the limerock cells averaged about 30 percent. TP averaged 105 milligrams per kilogram (mg/kg) with about 72 percent in the inorganic form. Of the inorganic P, about 92 percent was calcium bound. Of the TP, about 67 percent was in the calcium bound form and 23 percent was in residual organic forms. The scrape down cell had a slightly lower TP of 95 mg/kg with about 83 percent in the calcium bound form and the remainder largely in the residual organic form. The organic peat soil in Cell 4 was quite different from the other three cells. The TP averaged 350 mg/kg

with about 89 mg/kg (25 percent) in labile forms. About 236 mg/kg of TP (67 percent) was in moderately labile or residual organic forms.

#### EXHIBIT 4-1

PSTA Field-Scale Antecedent Soil TP Fractionation (February 2001)

Cell	Treatment	TP	Moisture Content %	Inorganic P Fractions			Organic P Fractions			
				Labile	Calcium-bond	Total Inorganic P	Labile	Moderate Labile	Residual	Total Organic P
FS-1	Limerock	106.0	32.8	6.14	69.5	75.6	5.73	4.98	29.6	40.3
FS-2	Limerock	104.8	27.8	5.38	72.2	77.6	4.50	2.87	19.6	27.0
FS-3	Caprock	95.0	47.5	3.88	78.5	82.4	5.73	1.50	28.9	36.1
FS-4	Peat	350.4	69.8	15.77	43.8	59.6	73.0	177.5	58.5	309.0

Note: units in mg/kg

Exhibit 4-2 summarizes the sorption isotherm data for the soils from the four Field-Scale Cells. The properties of the limestone and peat soils were very different. The limestone cells had linear adsorption coefficients between 380 and 1,079 liters per kilogram (L/kg) while the peat cell coefficient was 13 L/kg. The EPC<sub>0</sub> values were also very different between soils. The three limerock-based cells had EPC<sub>0</sub> values between 0.002 and 0.004 milligrams per liter (mg/L), while the peat soil value was 0.362 mg/L.

#### EXHIBIT 4-2

Summary of Sorption Isotherm Data from Field PSTA Cell Soils (February 2001)

Site	P Sorption Parameters			r <sup>2</sup>	P range mg/L
	Kd L/kg	So mg/kg	EPC <sub>0</sub> mg/L		
FS-1	380	-0.83	0.002	0.85	0.005-0.038
FS-2	614	-2.6	0.004	0.87	0.010-0.047
FS-3	1079	-2.5	0.002	0.78	0.007-0.034
FS-4	13	-4.8	0.362	0.83	0.462- 3.27

Note: Three samples composited on each transect; three composites composited for each cell for sorption.

Kd = linear adsorption coefficient

So = initial adsorbed P at C = 0 (negative sign indicated desorbable P)

EPC<sub>0</sub> = equilibrium P concentration

# Water Quality

---

## 5.1 Introduction

Water quality is being monitored at a number of stations in and around the Field-Scale PSTA site. Both surface water and groundwater are being tested. This monitoring includes a variety of field and laboratory measurements. The primary purpose of this monitoring is to assess the fate of TP in the surface water being introduced into these PSTA Cells. Other parameters are monitored to allow interpretation of the TP dynamics observed in these waters. Data trend charts for the study period are provided in Appendix B.

## 5.2 Surface Water

### 5.2.1 Field Parameters

Exhibit 5-1 provides a summary of the field parameter data collected during the POR. Monitoring points include the inflow canal and the outflow from each of the four PSTA demonstration cells.

- **Temperature:** Weekly average water temperature in the inflow canal varied between about 20 and 31 Celsius (°C), while average weekly temperatures at the cell outflows ranged from 20 to 35 °C.
- **pH:** Surface water pH increased through the three limerock cells from a value of about 7.6 units in the inflow canal to values of 8.4 in the Cell 1 outflow, 8.0 in the Cell 2 outflow, and 8.1 in the Cell 3 outflow. There was no change in the average pH between the inflow and the outflow of Cell 4.
- **Conductivity:** Conductivity was somewhat variable over time and between cells. The conductivity in the inflow canal ranged from 917 to 1,409 microhms per centimeter (µmhos/cm). Changes to the average conductivity observed between cell inflows and outflows were less than 17 percent and were variable between cells. Based on conductivity values, there did not appear to be a net concentration or dilution of water in these cells during this operational period. The concentration of total dissolved solids (TDS) showed the same general response as conductivity.
- **Dissolved oxygen:** The average dissolved oxygen (DO) in the inflow canal was about 4.6 mg/L. The cell outflow averages were between 5.1 and 8.4 mg/L during this operational period. The peat cell, Cell 4, had the lowest outflow DO.

### 5.2.2 Phosphorus

Exhibit 5-2 summarizes the P surface water data for the POR. Average TP in the inflow was 18 micrograms per liter (µg/L) during this period. Of this TP, 8 µg/L (44 percent) was in the dissolved form with about half-and-half as soluble reactive and dissolved organic P. Outflow TP averaged 18, 15, and 13 µg/L in Cells 1, 2, and 3, respectively. There was no outflow recorded for Cell 4 during this period of operation; samples of water collected from near the outflow structure averaged 32 µg/L.

**EXHIBIT 5-1**

Field Parameter Measurements from the Field Scale PSTA Cells, August to October 2001

Cell	Frequency	Time Period	Temperature (°C)	pH (units)	Condition (µmhos/cm)	Total Dissolved Solids (g/L)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
Inflow Canal	Weekly	08/05/01	28.57	7.30	983	0.629	42.2	3.30
		08/26/01	28.29	7.53	893	0.572	47.8	3.74
		09/02/01	29.30	7.82	917	0.586	38.3	2.96
		09/09/01	27.07	7.53	962	0.615	52.5	4.17
		09/16/01	30.72	7.78	1115	0.716	69.2	5.16
		09/23/01	28.27	7.50	1153	0.737	58.7	4.57
		09/30/01	24.84	7.53	1158	0.740	70.4	5.84
		10/07/01	25.55	7.64	1181	0.755	68.8	5.59
		10/14/01	26.10	7.80	1097	0.702	75.9	6.15
		10/21/01	26.90	7.65	1213	0.776	43.4	3.42
FSC-1	Weekly	10/28/01	19.60	7.97	1409	0.903	82.3	7.49
		08/05/01	30.84	8.28	904	0.578	110.8	8.21
		08/19/01	34.31	8.30	856	0.548	115.0	8.05
		08/26/01	31.18	8.25	898	0.575	91.5	6.73
		09/02/01	30.19	8.51	914	0.585	93.7	7.00
		09/09/01	27.13	8.61	750	0.480	101.0	7.98
		09/16/01	29.88	8.69	849	0.543	122.0	9.13
		09/23/01	28.13	8.43	953	0.610	113.2	8.78
		09/30/01	26.83	8.66	866	0.554	116.9	9.25
		10/07/01	27.21	8.35	1068	0.684	114.4	9.02
FSC-2	Weekly	10/14/01	26.77	8.36	1027	0.657	107.0	8.49
		10/21/01	26.18	8.21	1092	0.699	108.7	8.74
		10/28/01	20.49	8.60	1139	0.729	102.6	9.19
		08/26/01	28.42	7.95	958	0.611	51.6	4.03
		09/02/01	29.07	8.04	919	0.588	50.6	3.94
		09/09/01	25.99	8.10	665	0.426	45.8	3.69
		09/16/01	27.66	8.26	830	0.532	60.6	4.71
		09/23/01	25.71	7.90	1123	0.719	91.4	7.44
		09/30/01	26.55	8.00	1147	0.734	119.4	9.47
		10/07/01	27.46	8.08	1158	0.741	104.5	8.17
FSC-3	Weekly	10/14/01	25.97	7.93	1083	0.693	90.8	7.35
		10/21/01	26.36	7.94	1178	0.754	72.9	6.03
		10/28/01	19.85	8.05	1354	0.866	84.2	7.66
		07/29/01	26.55	8.10	313	0.200	90.5	7.27
		08/05/01	29.77	8.01	701	0.448	100.4	7.57
		08/19/01	34.52	7.68	990	0.634	105.1	7.33
		08/26/01	31.10	7.83	988	0.633	95.3	7.02
		09/02/01	30.09	8.12	941	0.602	89.6	6.71
		09/09/01	27.29	8.30	811	0.519	91.9	7.25
		09/16/01	29.65	8.17	1079	0.691	105.2	7.94
FSC-4	Weekly	09/23/01	29.83	7.94	1093	0.700	97.4	7.33
		09/30/01	25.00	7.64	1132	0.724	89.0	7.34
		10/07/01	25.14	8.05	1099	0.703	75.9	6.24
		10/14/01	25.90	7.91	1086	0.694	82.9	6.79
		10/21/01	26.05	8.07	1082	0.692	78.2	6.31
		10/28/01	19.87	8.01	1372	0.878	78.8	7.15
		09/02/01	28.30	7.78	927	0.594	36.2	2.85
		09/09/01	26.93	7.59	810	0.518	65.2	5.14
		09/16/01	29.21	7.50	1030	0.659	50.8	3.74
		09/23/01	26.81	7.59	1025	0.656	58.4	4.56
Inflow Canal	Monthly	09/30/01	27.01	7.67	1053	0.674	67.5	5.24
		10/07/01	27.22	7.73	1115	0.713	70.1	5.39
		10/14/01	26.01	7.64	1007	0.644	60.8	4.75
		10/28/01	22.29	7.82	1339	0.857	95.7	8.06
		Aug-01	28.43	7.41	938	0.600	45.0	3.52
		Sep-01	28.84	7.65	1036	0.664	54.7	4.22
FSC-1	Monthly	Oct-01	25.15	7.69	1189	0.761	66.6	5.50
		Aug-01	31.24	8.25	894	0.572	99.8	7.34
		Sep-01	28.76	8.55	865	0.553	106.0	8.13
FSC-2	Monthly	Oct-01	25.97	8.41	1038	0.665	110.4	8.90
		Aug-01	28.42	7.95	958	0.611	51.6	4.03
		Sep-01	25.96	7.98	1089	0.697	93.7	7.58
FSC-3	Monthly	Oct-01	26.93	8.02	1153	0.738	111.5	8.80
		Aug-01	29.58	7.93	732	0.469	95.4	7.23
		Sep-01	29.24	8.14	970	0.621	95.8	7.29
FSC-4	Monthly	Oct-01	24.95	7.93	1127	0.721	81.1	6.70
		Sep-01	27.35	7.59	961	0.615	59.7	4.64
		Oct-01	26.49	7.69	1096	0.702	68.3	5.33
Inflow Canal	POR	Aug - Oct 01	27.18	7.62	1083	0.693	57.9	4.63
FSC-1	POR	Aug - Oct 01	27.86	8.45	947	0.606	107.1	8.36
FSC-2	POR	Aug - Oct 01	26.68	8.01	1135	0.726	106.4	8.45
FSC-3	POR	Aug - Oct 01	29.27	8.07	897	0.574	95.4	7.26
FSC-4	POR	Sep - Oct 01	26.81	7.65	1046	0.669	65.1	5.07

## EXHIBIT 5-2

Phosphorus Water Quality Data Collected at the Field-Scale PSTA Cells, August to October 2001

Cell	Frequency	Time Period	Total Phosphorus				Total Dissolved Phosphorus				Dissolved Reactive Phosphorus				Total Particulate Phosphorus				Dissolved Organic Phosphorus			
			InfCnl	Inflow	stn_1/2	Outflow	InfCnl	Inflow	stn_1/2	Outflow	InfCnl	Inflow	stn_1/2	Outflow	InfCnl	Inflow	stn_1/2	Outflow	InfCnl	Inflow	stn_1/2	Outflow
FSC-1	Weekly	08/05/01	0.017	---	---	0.013	0.006	---	---	0.004	0.003	---	---	0.001	0.009	---	---	0.009	0.003	---	---	0.003
		08/26/01	0.022	0.024	0.019	0.025	0.010	0.009	0.008	0.007	0.002	0.001	0.001	0.001	0.013	0.015	0.011	0.014	0.008	0.008	0.007	0.006
		09/02/01	0.022	---	---	0.028	0.009	---	---	0.010	0.001	---	---	0.004	0.016	---	---	0.030	0.008	---	---	0.006
		09/09/01	0.021	---	---	0.014	0.007	---	---	0.006	0.004	---	---	0.001	0.011	---	---	0.008	0.003	---	---	0.005
		09/16/01	0.025	---	---	0.018	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
		10/07/01	0.016	---	---	0.014	0.008	---	---	0.006	0.004	---	---	0.002	0.007	---	---	0.007	0.004	---	---	0.004
		10/14/01	0.017	---	---	0.016	0.009	---	---	0.007	0.002	---	---	0.001	0.007	---	---	0.010	0.007	---	---	0.006
		10/21/01	0.015	0.026	0.015	0.015	0.007	0.012	0.007	0.006	0.013	0.003	0.003	0.003	0.007	0.015	0.008	0.009	0.000	0.009	0.004	0.003
		10/28/01	0.011	---	---	0.015	0.007	---	---	0.007	0.001	---	---	0.001	0.004	---	---	0.008	0.006	---	---	0.006
FSC-2	Weekly	08/26/01	0.020	---	---	0.017	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
		09/02/01	0.022	---	---	0.020	0.009	---	---	0.010	0.001	---	---	0.002	0.016	---	---	0.011	0.008	---	---	0.008
		09/09/01	0.021	---	---	0.016	0.007	---	---	0.006	0.004	---	---	0.002	0.011	---	---	0.010	0.003	---	---	0.004
		09/16/01	0.025	---	---	0.018	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
		09/23/01	0.019	0.018	0.015	0.015	0.007	0.007	0.007	0.007	0.003	0.003	0.003	0.004	0.010	0.011	0.008	0.009	0.004	0.005	0.004	0.003
		09/30/01	0.015	---	---	0.010	0.006	---	---	0.006	0.011	---	---	0.002	0.008	---	---	0.005	0.000	---	---	0.004
		10/07/01	0.016	---	---	0.013	0.008	---	---	0.008	0.004	---	---	0.002	0.007	---	---	0.004	0.004	---	---	0.006
		10/14/01	0.017	---	---	0.013	0.009	---	---	0.039	0.002	---	---	0.001	0.007	---	---	0.000	0.007	---	---	0.038
		10/21/01	0.015	0.026	0.014	0.014	0.007	0.009	0.008	0.008	0.013	0.003	0.003	0.003	0.007	0.017	0.006	0.006	0.000	0.006	0.005	0.005
		10/28/01	0.011	---	---	0.012	0.007	---	---	0.006	0.001	---	---	0.001	0.004	---	---	0.006	0.006	---	---	0.005
FSC-3	Weekly	08/05/01	0.017	---	---	0.011	0.006	---	---	0.006	0.003	---	---	0.003	0.009	---	---	0.006	0.003	---	---	0.003
		08/26/01	0.022	0.021	0.017	0.020	0.010	0.009	0.008	0.008	0.002	0.002	0.001	0.001	0.013	0.012	0.009	0.012	0.008	0.007	0.007	0.007
		09/02/01	0.022	---	---	0.015	0.009	---	---	0.007	0.001	---	---	0.006	0.016	---	---	0.009	0.008	---	---	0.001
		09/09/01	0.021	---	---	0.013	0.007	---	---	0.005	0.004	---	---	0.001	0.011	---	---	0.008	0.003	---	---	0.004
		09/16/01	0.022	---	---	0.012	0.006	---	---	0.006	0.007	---	---	0.002	0.013	---	---	0.006	0.000	---	---	0.004
		09/23/01	0.019	0.015	0.014	0.012	0.007	0.007	0.006	0.005	0.003	0.002	0.003	0.004	0.010	0.008	0.008	0.007	0.004	0.005	0.003	0.001
		09/30/01	0.015	---	---	0.014	0.006	---	---	0.006	0.011	---	---	0.003	0.008	---	---	0.012	0.000	---	---	0.003
		10/07/01	0.016	---	---	0.013	0.008	---	---	0.005	0.004	---	---	0.001	0.007	---	---	0.006	0.004	---	---	0.004
		10/14/01	0.017	---	---	0.013	0.009	---	---	0.007	0.002	---	---	0.003	0.007	---	---	0.006	0.007	---	---	0.004
		10/21/01	0.015	0.018	0.011	0.013	0.007	0.007	0.006	0.006	0.013	0.003	0.002	0.002	0.007	0.011	0.005	0.006	0.000	0.004	0.004	0.004
		10/28/01	0.011	---	---	0.011	0.007	---	---	0.006	0.001	---	---	0.001	0.004	---	---	0.005	0.006	---	---	0.005
FSC-4	Weekly*	09/09/01	0.021	---	---	0.047	0.007	---	---	0.012	0.004	---	---	0.004	0.011	---	---	0.031	0.003	---	---	0.008
		10/14/01	0.017	---	---	0.024	0.009	---	---	0.012	0.002	---	---	0.002	0.007	---	---	0.010	0.007	---	---	0.010
		10/28/01	0.011	---	---	0.018	0.007	---	---	0.010	0.001	---	---	0.002	0.004	---	---	0.008	0.006	---	---	0.008
FSC-1	Monthly	Aug-01	0.019	0.024	0.019	0.019	0.008	0.009	0.008	0.006	0.003	0.001	0.001	0.001	0.011	0.015	0.011	0.011	0.006	0.008	0.007	0.005
		Sep-01	0.022	---	---	0.020	0.008	---	---	0.008	0.003	---	---	0.003	0.014	---	---	0.019	0.006	---	---	0.006
		Oct-01	0.015	0.026	0.015	0.015	0.008	0.012	0.007	0.007	0.005	0.003	0.003	0.002	0.006	0.015	0.008	0.009	0.004	0.009	0.004	0.005
FSC-2	Monthly	Aug-01	0.020	---	---	0.017	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
		Sep-01	0.021	0.018	0.015	0.017	0.008	0.007	0.007	0.008	0.003	0.003	0.003	0.003	0.012	0.011	0.008	0.010	0.005	0.005	0.004	0.005
		Oct-01	0.015	0.026	0.014	0.012	0.007	0.009	0.008	0.013	0.006	0.003	0.003	0.002	0.007	0.017	0.006	0.004	0.003	0.006	0.005	0.012
FSC-3	Monthly	Aug-01	0.019	0.021	0.017	0.015	0.008	0.009	0.008	0.007	0.003	0.002	0.001	0.002	0.011	0.012	0.009	0.009	0.006	0.007	0.007	0.005
		Sep-01	0.021	0.015	0.014	0.013	0.007	0.007	0.006	0.006	0.004	0.002	0.003	0.003	0.013	0.008	0.008	0.007	0.004	0.005	0.003	0.002
		Oct-01	0.015	0.018	0.011	0.013	0.007	0.007	0.006	0.006	0.006	0.003	0.002	0.002	0.007	0.011	0.005	0.007	0.003	0.004	0.004	0.004
FSC-4	Monthly*	Aug-01	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
		Sep-01	0.021	---	---	0.047	0.007	---	---	0.012	0.004	---	---	0.004	0.011	---	---	0.031	0.003	---	---	0.008
		Oct-01	0.015	---	---	0.022	0.008	---	---	0.011	0.002	---	---	0.002	0.006	---	---	0.009	0.007	---	---	0.009
FSC-1	POR	Aug - Oct 01	0.018	0.025	0.017	0.018	0.008	0.010	0.008	0.007	0.004	0.002	0.002	0.002	0.009	0.015	0.010	0.012	0.005	0.008	0.006	0.005
FSC-2	POR	Aug - Oct 01	0.018	0.022	0.015	0.015	0.008	0.008	0.008	0.011	0.005	0.003	0.003	0.002	0.009	0.014	0.007	0.006	0.004	0.005	0.005	0.009
FSC-3	POR	Aug - Oct 01	0.018	0.018	0.014	0.013	0.007	0.008	0.007	0.006	0.005	0.002	0.002	0.002	0.010	0.010	0.007	0.008	0.004	0.005	0.005	0.004
FSC-4	POR	Sept - Oct 01	0.017	---	---	0.032	0.008	---	---	0.011	0.002	---	---	0.003	0.007	---	---	0.016	0.005	---	---	0.009

All values in µg/L.

\*No outflow from FS-4 this period. Phosphorus values shown are analyses of grab samples collected near the outflow structures.

Exhibit 5-3 provides an estimated mass balance for TP in the Field-Scale Cells (FSC) 1 through 3 during the POR. Mass loadings to the three cells were highly variable due to variable inflow pumping rates and ranged from 0.45 to 0.80 grams per square meter per year ( $\text{g}/\text{m}^2/\text{y}$ ). Cell 3 received the highest water and TP load during this period. Average TP removal rates were also quite variable, ranging from 0.30 to 0.53  $\text{g}/\text{m}^2/\text{y}$ . Resulting  $k_d$  values ranged from about 1.3 to 11.3 meters per year ( $\text{m}/\text{y}$ ).

### 5.2.2 Nitrogen

Exhibit 5-4 summarizes monthly nitrogen data. Average inflow total nitrogen (TN) was between 2.9 and 3.2  $\text{mg}/\text{L}$ . The majority of this TN was in the organic form (about 96 percent). Average outflow TN for the three cells ranged from 2.5 to 3.0  $\text{mg}/\text{L}$  with no significant increase or decrease observed for any of the nitrogen forms. The TN mass balance summarized in Exhibit 5-4 showed no net increase or removal in these cells.

### 5.2.3 Other Parameters

Exhibit 5-5 summarizes the analytical data for total organic carbon (TOC), total suspended solids (TSS), calcium (Ca), alkalinity, and chlorides. Data were only available for Cells 1 through 3. TOC concentrations were roughly unchanged between the cell inlets and outlets. The outflow TSS concentrations for these three cells were all less than about 3  $\text{mg}/\text{L}$ . Calcium concentrations declined slightly in all cells (10 to 16 percent). There were no consistent changes in alkalinity or chlorides in any of the cells.

## 5.3 Groundwater

Installation of the groundwater wells was completed in August 2001. Exhibit 5-6 summarizes the TP groundwater data for September and October 2001. Average TP in all wells was 14  $\mu\text{g}/\text{L}$ , ranging from 10 to 23  $\mu\text{g}/\text{L}$  during this POR. TP concentrations averaged 13.8  $\mu\text{g}/\text{L}$  in the internal wells. The well located on the Western berm of FSC-4 exhibited the highest average concentration of 21  $\mu\text{g}/\text{L}$ . The lowest average concentration was observed at the well located near the outflow of FSC-3 with 10  $\mu\text{g}/\text{L}$ .

**EXHIBIT 5-3**

Total Phosphorus Mass Balance Summary from the Field-Scale PSTA Cells, August to October 2001

Cell	Frequency	Time Period	Total Phosphorus		Flow (m <sup>3</sup> /d)			Hydraulic Loading Rate (cm/d)			MB_TP (g/m <sup>2</sup> /y)		Removal		Calc_k (m/y)
			Inflow	Outflow	Inflow	Outflow	Average	q_in	q_out	q_avg	Inflow	Outflow	(g/m <sup>2</sup> /y)	(%)	
FSC-1	Weekly	08/05/01	0.017	0.013	1,084	2,018	1,551	5.36	9.97	7.67	0.323	0.455	-0.132	-40.97	7.77
		08/26/01	0.022	0.025	2,530	1,082	1,806	12.50	5.35	8.92	1.004	0.483	0.521	51.91	-3.84
		09/02/01	0.022	0.028	723	202	462	3.57	1.00	2.28	0.280	0.102	0.179	63.70	-2.20
		09/09/01	0.021	0.014	1,446	275	860	7.14	1.36	4.25	0.535	0.070	0.465	87.00	5.92
		09/16/01	0.025	0.018	1,084	46	565	5.36	0.23	2.79	0.489	0.015	0.474	96.94	3.35
		10/07/01	0.016	0.014	1,446	680	1,063	7.14	3.36	5.25	0.404	0.165	0.239	59.06	2.65
		10/14/01	0.017	0.016	1,446	266	856	7.14	1.32	4.23	0.443	0.077	0.367	82.67	0.94
		10/21/01	0.021	0.015	1,807	1,134	1,471	8.93	5.61	7.27	0.668	0.307	0.361	54.07	8.29
		10/28/01	0.011	0.015	0	0	0	0.00	0.00	0.00	0.000	0.000	0.000	---	0.00
FSC-2	Weekly	08/26/01	0.020	0.017	2,891	17	1,454	14.29	0.09	7.19	1.043	0.005	1.038	99.49	4.26
		09/02/01	0.022	0.020	964	245	604	4.76	1.21	2.99	0.374	0.089	0.284	76.06	0.65
		09/09/01	0.021	0.016	2,409	0	1,205	11.91	0.00	5.95	0.891	0.000	0.891	100.00	6.08
		09/16/01	0.025	0.018	1,446	445	946	7.14	2.20	4.67	0.652	0.145	0.507	77.81	5.60
		09/23/01	0.019	0.015	3,373	2,299	2,836	16.67	11.36	14.02	1.141	0.622	0.519	45.46	11.42
		09/30/01	0.015	0.010	3,373	2,153	2,763	16.67	10.64	13.65	0.882	0.388	0.494	55.99	18.52
		10/07/01	0.016	0.013	3,373	1,888	2,631	16.67	9.33	13.00	0.943	0.426	0.517	54.85	10.21
		10/14/01	0.017	0.013	3,373	1,590	2,482	16.67	7.86	12.26	1.034	0.373	0.661	63.95	12.01
		10/21/01	0.021	0.014	3,373	2,062	2,717	16.67	10.19	13.43	1.247	0.502	0.745	59.75	20.48
		10/28/01	0.011	0.012	3,373	731	2,052	16.67	3.61	10.14	0.669	0.158	0.511	76.36	-3.22
FSC-3	Weekly	08/05/01	0.017	0.011	1,338	3,063	2,200	6.61	15.14	10.87	0.398	0.608	-0.210	-52.68	16.09
		08/26/01	0.021	0.020	3,121	2,450	2,785	15.42	12.11	13.77	1.154	0.862	0.292	25.34	2.51
		09/02/01	0.022	0.015	3,121	254	1,688	15.42	1.26	8.34	1.210	0.069	1.142	94.31	10.96
		09/09/01	0.021	0.013	3,121	2,725	2,923	15.42	13.47	14.45	1.154	0.627	0.527	45.69	25.04
		09/16/01	0.022	0.012	1,338	1,915	1,626	6.61	9.47	8.04	0.531	0.423	0.108	20.27	17.18
		09/23/01	0.018	0.012	2,675	2,204	2,439	13.22	10.89	12.06	0.844	0.477	0.367	43.51	16.60
		09/30/01	0.015	0.014	1,338	2,892	2,115	6.61	14.30	10.45	0.350	0.744	-0.394	-112.52	0.66
		10/07/01	0.016	0.013	2,229	2,648	2,439	11.02	13.09	12.05	0.623	0.597	0.026	4.21	9.46
		10/14/01	0.017	0.013	3,121	2,516	2,819	15.42	12.44	13.93	0.957	0.590	0.367	38.34	13.64
		10/21/01	0.017	0.013	3,121	1,243	2,182	15.42	6.14	10.78	0.929	0.280	0.649	69.83	10.93
FSC-1	Monthly	10/28/01	0.011	0.011	3,121	2,925	3,023	15.42	14.46	14.94	0.619	0.580	0.039	6.27	0.00
		Aug-01	0.019	0.019	1,714	758	1,236	8.47	3.75	6.11	0.595	0.255	0.340	57.18	0.74
		Sep-01	0.022	0.020	928	158	543	4.58	0.78	2.68	0.365	0.058	0.307	84.10	0.65
FSC-2	Monthly	Oct-01	0.017	0.015	1,306	535	921	6.45	2.65	4.55	0.394	0.143	0.250	63.56	1.96
		Aug-01	0.020	0.017	1,414	0	707	6.99	0.00	3.50	0.510	0.000	0.510	100.00	2.07
		Sep-01	0.021	0.017	2,136	777	1,456	10.56	3.84	7.20	0.806	0.239	0.567	70.34	5.35
FSC-3	Monthly	Oct-01	0.016	0.012	3,373	1,759	2,566	16.67	8.69	12.68	0.987	0.388	0.599	60.71	13.10
		Aug-01	0.019	0.015	2,316	1,481	1,898	11.44	7.32	9.38	0.773	0.408	0.365	47.27	6.62
		Sep-01	0.020	0.013	2,601	1,825	2,213	12.85	9.02	10.94	0.956	0.433	0.523	54.74	17.50
FSC-3	Monthly	Oct-01	0.015	0.013	2,517	2,356	2,436	12.44	11.64	12.04	0.696	0.545	0.151	21.66	7.82
		Aug - Oct 01	0.019	0.018	1,320	472	896	6.52	2.33	4.43	0.451	0.149	0.302	66.92	1.25
		Aug - Oct 01	0.018	0.015	2,310	895	1,602	11.42	4.42	7.92	0.766	0.234	0.532	69.45	6.86
FSC-3	POR	Aug - Oct 01	0.018	0.013	2,476	1,911	2,194	12.24	9.45	10.84	0.798	0.463	0.335	41.98	11.29

**EXHIBIT 5-4**

Nitrogen Water Quality Data and Total Nitrogen Mass Balances at the Field-Scale PSTA Cells, August to October 2001

Cell	Frequency	Time Period	TN_mg/L		TKN_mg/L		NO <sub>2</sub> NO <sub>3</sub> _mg/L		NH <sub>3</sub> _mg/L		OrgN_mg/L		Total Nitrogen (mg/L)	
			Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
FSC-1	Monthly	Aug-01	2.53	2.86	2.53	2.86	0.03	0.03	0.08	0.09	2.45	2.78	2.53	2.86
		Oct-01	3.26	3.23	3.14	3.23	0.12	0.03	0.14	0.06	3.00	3.17	3.26	3.23
FSC-2	Monthly	Sep-01	2.68	2.45	2.63	2.45	0.05	0.03	0.10	0.05	2.53	2.40	2.68	2.45
		Oct-01	3.63	2.48	3.45	2.39	0.18	0.09	0.08	0.05	3.37	2.34	3.63	2.48
FSC-3	Monthly	Aug-01	2.57	2.97	2.57	2.97	0.03	0.03	0.11	0.07	2.46	2.90	2.57	2.97
		Sep-01	2.91	2.53	2.91	2.53	0.03	0.03	0.07	0.05	2.84	2.48	2.91	2.53
		Oct-01	3.20	2.24	2.98	2.24	0.22	0.03	0.13	0.08	2.85	2.16	3.20	2.24
FSC-1	POR	Aug - Oct 01	2.89	3.05	2.83	3.05	0.07	0.03	0.11	0.07	2.72	2.97	2.89	3.05
FSC-2	POR	Sep - Oct 01	3.16	2.47	3.04	2.42	0.12	0.06	0.09	0.05	2.95	2.37	3.16	2.47
FSC-3	POR	Aug - Oct 01	2.89	2.58	2.82	2.58	0.09	0.03	0.10	0.07	2.72	2.51	2.89	2.58

Cell	Frequency	Time Period	Flow (m <sup>3</sup> /d)			Hydraulic Loading Rate (cm/d)			MB_TN (g/m <sup>2</sup> /y)		Removal		Calc_k (m/y)
			Inflow	Outflow	Average	q_in	q_out	q_avg	Inflow	Outflow	(g/m <sup>2</sup> /y)	(%)	
FSC-1	Monthly	Aug-01	1,714	758	1,236	8.47	3.75	6.11	78.22	39.13	39.09	49.97	-2.73
		Oct-01	1,306	535	921	6.45	2.65	4.55	76.67	31.19	45.48	59.32	0.13
FSC-2	Monthly	Sep-01	2,136	777	1,456	10.56	3.84	7.20	103.27	34.32	68.95	66.76	2.36
		Oct-01	3,373	1,759	2,566	16.67	8.69	12.68	220.87	78.68	142.18	64.38	17.63
FSC-3	Monthly	Aug-01	2,316	1,481	1,898	11.44	7.32	9.38	107.35	79.36	27.99	26.07	-4.95
		Sep-01	2,601	1,825	2,213	12.85	9.02	10.94	136.53	83.28	53.25	39.00	5.59
		Oct-01	2,517	2,356	2,436	12.44	11.64	12.04	145.29	95.19	50.10	34.48	15.68
FSC-1	POR	Aug - Oct 01	1,320	472	896	6.52	2.33	4.43	68.87	25.91	42.96	62.38	-0.83
FSC-2	POR	Sep - Oct 01	2,310	895	1,602	11.42	4.42	7.92	131.45	39.78	91.68	69.74	7.13
FSC-3	POR	Aug - Oct 01	2,476	1,911	2,194	12.24	9.45	10.84	129.25	88.95	40.30	31.18	4.54

**EXHIBIT 5-5**

Averages of Water Quality Data Collected at the Field-Scale PSTA Cells, August to October 2001

Cell	Frequency	Time Period	Total Organic Carbon		Total Suspended Solids		Calcium		Alkalinity		Chlorides	
			Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
FSC-1	Monthly	Aug-01	36.0	32.0	0.8	1.1	45.7	43.5	200	188	---	---
		Oct-01	40.5	40.0	5.3	2.0	53.5	44.1	295	220	167	154
FSC-2	Monthly	Sep-01	41.0	41.0	7.5	2.5	79.2	77.2	268	275	155	164
		Oct-01	41.0	40.0	2.8	0.8	62.9	50.4	280	270	166	154
FSC-3	Monthly	Aug-01	40.0	32.0	2.8	1.3	52.5	50.2	210	210	---	---
		Sep-01	42.0	42.0	5.0	5.3	77.4	64.7	270	250	153	158
		Oct-01	42.0	38.0	2.9	2.9	64.0	47.6	270	230	154	143
FSC-1	POR	Aug - Oct 01	38.3	36.0	3.1	1.5	49.6	43.8	248	204	167	154
FSC-2	POR	Sep - Oct 01	41.0	40.5	5.2	1.7	71.0	63.8	274	273	161	159
FSC-3	POR	Aug - Oct 01	41.3	37.3	3.6	3.2	64.6	54.2	250	230	154	151

All values in mg/L.

**EXHIBIT 5-6**

TP Concentrations in FS Groundwater Wells, September – October 2001

Groundwater Well	September 2001	October 2001	S
			Average
Perimeter Wells			
FSC-1 Eastern Berm	13.0	13.0	13.0
FSC-1 Inflow Berm	11.0	11.0	11.0
FSC-3 Inflow Berm	13.0	11.0	12.0
FSC-4 Western Berm	23.0	19.0	21.0
FSC-3 Outflow Berm	10.0	10.0	10.0
FSC-1 Outflow Berm	17.0	14.0	15.5
Combined Summary	14.5	13.0	13.8
Internal Wells			
FSC-1	20.0	12.0	16.0
FSC-2	16.0	13.0	14.5

# Biological Community

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## 6.1 Introduction

Biological sampling is being conducted in the PSTA Field-Scale Cells to document the form and function of the biological community. This sampling includes documentation of periphyton biomass; periphyton content of calcium, phosphorus, and nitrogen; chlorophyll; and algal taxonomy. Macrophyte biomass is also measured when vascular plants are encountered in periphyton core samples. Community metabolism is being estimated from the cells based on continuous measurements of DO.

## 6.2 Periphyton

Exhibit 6-1 presents a summary of periphyton data from the PSTA FSC 1 through 3 for the quarter. Average dry weight biomass was highest in Cell 2 at about 929 g/m<sup>2</sup> and lowest in Cell 3 at 368 g/m<sup>2</sup>. Average ash-free dry weight biomass in these cells ranged from 67 to 133 g/m<sup>2</sup>. Calcium made up a relatively small proportion of the ash weight in Cells 1 and 2 (10 to 12 percent) and was a higher proportion in Cell 3 (19 percent). Periphyton TP ranged from 0.08 to 0.23 g/m<sup>2</sup> (240 to 480 mg/kg) and was about 0.15 percent of the ash free dry weight in Cells 1, 0.17 percent in Cell 2, and 0.12 percent in Cell 3 periphyton.

Algal biovolume was highest in Cell 2 and lowest in Cell 3. On a biovolume basis, blue green algal species dominated Cell 1 periphyton, green algal species dominated Cell 2 periphyton, and diatoms dominated the algal flora in Cell 3.

Appendix C presents the detailed list of algal species, cell counts, and biovolumes for the Field-Scale PSTAs during this quarter.

Exhibit 6-2 presents a summary of the detailed periphyton phosphorus fractionation analyses from the Field-Scale PSTA Cells. TP ranged from 240 to 480 mg/kg with approximately 60 percent in the organic form. Of this organic TP about 37 percent was recalcitrant.

## 6.3 Macrophytes

Biomass estimates were made for macrophytes encountered in the periphyton core samples. Dominant macrophyte species included the macroalga *Chara*, spikerush (*Eleocharis cellulosa*), and narrow-leaf cattail (*Typha latifolia*). Average above-ground, dry-weight macrophyte biomass ranged from a low of 19.2 g/m<sup>2</sup> in Cell 3 to a high of 182 g/m<sup>2</sup> in Cell 1 (Exhibit 6-3). There were no macrophyte biomass estimates from Cell 4 during this POR.

## EXHIBIT 6-1

Periphyton Data from the Field-Scale PSTA Cells, August to October 2001

		Monthly Average								POR Average		
		Cell 1			Cell 2		Cell 3			Cell 1	Cell 2	Cell 3
Parameter	Units	Aug-01	Sep-01	Oct-01	Sep-01	Oct-01	Aug-01	Sep-01	Oct-01	Aug - Oct 01	Sep - Oct 01	Aug - Oct 01
Periphyton	Dry Wt	---	---	562	---	929	---	---	368	562	929	368
Biomass	Ash Wt	---	---	381	---	712	---	---	294	381	712	294
	(g/m <sup>2</sup> )	---	43.2	163	77.8	189	85.0	39.7	77.1	103	133	67.3
Ca	(g/m <sup>2</sup> )	44.7	51.3	20.3	129	42.1	108	52.7	11.4	38.8	85.4	57.2
	(mg/kg)	---	---	36071	---	45333	---	---	30976	36071	45333	30976
Chl_a	(g/m <sup>2</sup> )	0.038	---	0.239	---	0.328	0.056	---	0.140	0.139	0.328	0.098
	(mg/kg)	---	---	425	---	353	---	---	380	425	353	380
TP	(g/m <sup>2</sup> )	0.101	0.078	0.270	0.206	0.245	0.093	0.068	0.088	0.150	0.225	0.083
	(mg/kg)	---	---	480	---	263	---	---	240	480	263	240
TIP	(g/m <sup>2</sup> )	0.027	0.016	0.030	0.057	0.038	0.018	0.021	0.026	0.024	0.047	0.021
	(mg/kg)	---	---	53.4	---	40.9	---	---	70.1	53.4	40.9	70
TKN	(g/m <sup>2</sup> )	---	---	6.32	---	7.37	---	---	3.69	6.32	7.37	3.69
	(mg/kg)	---	---	11250	---	7933	---	---	10029	11250	7933	10029
Blue-Green	(# cells/m <sup>2</sup> )*10 <sup>9</sup>	---	---	124	---	232	---	---	157	124	232	157
Algae	(cm <sup>3</sup> /cm <sup>2</sup> )	---	---	14.69	---	2.13	---	---	1.68	14.69	2.13	1.68
	(# taxa)	---	---	14	---	12	---	---	10	14	12	10
	(# cells/m <sup>2</sup> )*10 <sup>9</sup>	---	---	1.94	---	11.0	---	---	4.63	1.94	10.99	4.63
Diatoms	(cm <sup>3</sup> /cm <sup>2</sup> )	---	---	1.08	---	6.14	---	---	1.87	1.08	6.14	1.87
	(# taxa)	---	---	9	---	15	---	---	8	9	15	8
	(# cells/m <sup>2</sup> )*10 <sup>9</sup>	---	---	1.46	---	2.50	---	---	2.89	1.46	2.50	2.89
Green Algae	(cm <sup>3</sup> /cm <sup>2</sup> )	---	---	0.29	---	50.30	---	---	0.16	0.29	50.30	0.16
	(# taxa)	---	---	5	---	5	---	---	4	5	5	4
	(# cells/m <sup>2</sup> )*10 <sup>9</sup>	---	---	127	---	246	---	---	165	119	246	165
Total Taxa	(cm <sup>3</sup> /cm <sup>2</sup> )	---	---	16.05	---	58.57	---	---	3.71	16.05	58.57	3.71
	(# taxa)	---	---	21	---	32	---	---	22	21	32	22
Evenness	---	---	---	0.693	---	0.576	---	---	0.623	0.693	0.576	0.623
SWDI	---	---	---	3.33	---	2.88	---	---	2.78	3.33	2.88	2.78

**EXHIBIT 6-2**

Periphyton Phosphorus Fractionation Data Summary from the Field-Scale PSTA Cells, October 2001

Cell	Moisture %	TP mg/kg	Inorganic Phosphorus Fractions		Organic Phosphorus Fractions		Residual
			Labile	Calcium-Bound	Labile	Moderately Labile	
FS-1	75.0	176.5	1.730	71.04	42.16	15.32	40.63
FS-2	77.2	142.7	1.586	47.40	46.60	10.04	26.56
FS-3	84.5	160.2	1.718	45.01	49.12	10.96	37.52

**EXHIBIT 6-3**

Summary of Macrophyte Biomass, August to October 2001

Cell	Frequency	Time Period	Dry Weight		Total Solids
			g	g/m <sup>2</sup>	%
FS-1	Monthly	Sep-01	11.9	97.1	8.3
		Oct-01	32.7	265.9	11.6
FS-2	Monthly	Sep-01	4.6	56.6	13.2
		Oct-01	5.8	70.3	11.3
FS-3	Monthly	Aug-01	0.9	14.2	45.4
		Sep-01	3.4	27.6	11.2
		Oct-01	1.9	15.8	9.9
FS-1	POR	Sep - Oct 01	22.3	181.5	15.6
FS-2	POR	Sep - Oct 01	5.2	63.4	14.8
FS-3	POR	Aug - Oct 01	2.1	19.2	12.9

## 6.4 Community Metabolism

Exhibit 6-4 summarizes the community metabolism data. Average POR gross primary productivity (GPP) ranged from 2.3 grams (g) of O<sub>2</sub> per square meter per day (O<sub>2</sub>/m<sup>2</sup>/d) in Cell 3 to 4.1 g of O<sub>2</sub>/m<sup>2</sup>/d in Cell 2. Community respiration (CR) ranged from 2.4 g of O<sub>2</sub>/m<sup>2</sup>/d in Cell 3 to 4.0 g of O<sub>2</sub>/m<sup>2</sup>/d in Cell 2. The average ratio between GPP and CR in these cells was slightly higher than 1 in Cells 1 and 2 and less than 1 in Cell 3. There was a very small amount of net productivity estimated for Cells 1 and 2 and a negative net production estimated in Cell 3.

**EXHIBIT 6-4**

Metabolism Data from the Field-Scale PSTA Cells, August to October 2001

Cell	Frequency	Time Period	GPP(day)	CR(24hr)	P/R Ratio	NPP(24hr)	NPP(day)	Avg Night Res	PAR(24hr)	Efficiency
			g/m <sup>2</sup> /d	g/m <sup>2</sup> /d		g/m <sup>2</sup> /d	g/m <sup>2</sup> /d		E/m <sup>2</sup> /d	%
FS-1	Weekly	08/26/2001	3.09	3.24	0.95	-0.15	1.20	0.14	31.7	1.898
		09/02/2001	2.56	2.56	1.00	0.00	1.07	0.11	14.0	6.739
		09/09/2001	2.70	2.51	1.07	0.18	1.23	0.10	13.3	4.896
		09/16/2001	3.99	3.86	1.03	0.13	1.73	0.16	5.3	14.399
		09/23/2001	2.78	2.66	1.05	0.12	1.29	0.11	7.5	8.435
		09/30/2001	2.50	2.40	1.04	0.10	1.12	0.10	32.8	1.508
		10/07/2001	2.63	2.83	0.93	-0.20	1.07	0.12	29.8	1.694
		10/14/2001	2.99	3.00	1.00	-0.01	1.37	0.13	18.2	3.246
		10/21/2001	3.76	3.59	1.05	0.17	1.82	0.15	17.7	4.424
		10/28/2001	1.58	1.74	0.91	-0.16	0.64	0.07	17.4	1.759
FS-2	Weekly	09/23/2001	2.99	2.36	1.27	0.64	1.72	0.10	9.3	7.195
		09/30/2001	4.45	4.37	1.02	0.08	1.90	0.18	31.1	2.935
		10/07/2001	4.42	4.35	1.02	0.07	1.99	0.18	28.0	3.186
FS-3	Weekly	08/26/2001	2.23	2.48	0.90	-0.24	0.79	0.10	31.4	1.364
		09/02/2001	2.21	2.28	0.97	-0.07	0.89	0.10	14.1	6.101
		09/09/2001	1.84	1.81	1.02	0.03	0.78	0.08	13.3	3.469
		09/16/2001	2.39	2.53	0.95	-0.14	1.02	0.11	5.1	8.892
		09/23/2001	3.25	3.26	1.00	-0.01	1.25	0.14	6.2	11.700
FS-1	Monthly	Aug-01	3.21	3.35	0.96	-0.14	1.26	0.14	32.5	1.937
		Sep-01	2.78	2.70	1.03	0.08	1.22	0.11	12.5	7.117
		Oct-01	2.80	2.80	1.00	0.00	1.26	0.12	23.6	2.599
FS-2	Monthly	Sep-01	3.52	3.17	1.11	0.35	1.73	0.13	17.4	5.670
		Oct-01	4.42	4.30	1.03	0.12	1.97	0.18	29.0	3.124
FS-3	Monthly	Aug-01	2.15	2.43	0.89	-0.28	0.73	0.10	32.2	1.262
		Sep-01	2.34	2.39	0.98	-0.05	0.96	0.10	10.8	6.788
FS-1	POR	Aug - Oct 01	2.83	2.81	1.01	0.02	1.24	0.12	19.8	4.446
FS-2	POR	Sep - Oct 01	4.15	3.96	1.05	0.19	1.90	0.17	25.5	3.888
FS-3	POR	Aug - Sep 01	2.31	2.39	0.96	-0.09	0.92	0.10	14.5	5.835

 Diffusion Rate: 0.01 g/m<sup>2</sup>/h

## SECTION 7

# Continuing Operations Plan

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## 7.1 Introduction

Monitoring of the Field-Scale PSTA systems was originally intended to be finished in early 2002. Due to water availability issues and mechanical problems associated with the inflow pumps, system start up was delayed. Accordingly, the Field-Scale monitoring period was extended with operations and monitoring until the end of January 2002, with project closure planned in early February 2002. Subsequently, in recognition of the need for a longer study POR, the District elected to extend monitoring through December 2002. Depending on the length of time necessary to finish periphyton grow in, this additional testing will allow up to a maximum of about one year of post-startup operations and data collection.

## 7.2 Phase 3 Scope

The Phase 3 Scope includes a continuation of the routine sampling plan as described in Section 1 of this report. This scope extension adds one additional task: a study of soil pre-treatment options and effectiveness.

### 7.2.1 Efficacy of Soil Amendments

The purpose of this new work is to document the types of soil amendments that have been successfully used elsewhere for TP retention and to test their efficacy in concert with on-site peat soils. This new task includes three subtasks:

- Literature Review
- Soil Mixture Characterization and Phosphorus Sorption/Desorption Study
- Mesocosm Study

The literature review will itemize the known advantages and disadvantages of a number of possible soil amendments such as alum, alum sludge, and calcium rich chemicals. The sorption/desorption study will document the properties of the most highly ranked soil treatments when mixed with on-site peat soils. These bench-scale tests will be conducted in the laboratory. The final part of the study will be a mesocosm evaluation of the efficacy of the top-ranked soil amendments. These mesocosms will be flow-through systems, and TP release and uptake will be monitored for a period of about 5 months.

### 7.2.2 Field-Scale Cell Operations Plan

This section outlines the plan for operation of the Field-Scale Cells during this project phase. The basic goal of this plan is to provide a fairly realistic demonstration of the ecological succession and performance of large-scale PSTAs within the current project constraints.

The primary purpose of the Field-Scale PSTA 3 work is to quantify TP removal performance at a larger scale and to test the effects of two design variables on this performance, namely

soil type and flow velocity (length-to-width ratio). This primary goal will be accomplished by continuously loading the PSTA Field-Scale Cells at the highest design loading rate of about 12 cm/d. This relatively high hydraulic loading rate will accelerate plant community development and is likely to shorten other potential startup transient behaviors such as soil sorption/desorption and natural reduction of groundwater infiltration rates.

Phase 1 and 2 PSTA research found that periphyton-dominated plant communities could be relatively easily established in constructed wetlands, but that rooted emergent macrophytes tended to eventually increase in dominance over a one- or two-year development period. Factors that were observed to decrease the rate of this macrophyte invasion were increasing water depth, imported soils with apparent low density of macrophyte seeds, and the origin of source waters. Hand pulling and herbicides were also found to be effective at control of emergent macrophytes in the small-scale mesocosms.

The proposed operations plan will use water depth to attempt to inhibit macrophyte invasion. Herbicides will also be used selectively to assist with plant control. A recommended water depth and loading schedule for each of the cells during the period of this project is proposed as follows:

- January 1 – April 30, 2002: 30 cm and 12 cm/d
- May 1 – May 15, 2002: dry and no inflow
- May 15 – June 30, 2002: 30 cm and 6 cm/d
- July 1 – August 31, 2002: 60 cm and 12 cm/d
- September 1 – September 15, 2002: dry and no inflow
- September 16 – December 31, 2002: 30 cm and 12 cm/d

Herbicides will be applied selectively during this period to reduce the invasion rate of cattails. Submerged aquatic vegetation will not be controlled other than through the dry-out planned for May and early June 2002.

## SECTION 8

# Works Cited

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CH2M HILL. November 2001. *PSTA Research and Demonstration Project (C-E8624); Draft Supplemental Technology Standards of Comparison (STSOC) Analysis Conceptual Designs and Planning Level Cost Estimates for a Full-Scale Periphyton Stormwater Treatment Area*. Prepared for the South Florida Water Management District. November 2001.

CH2M HILL. August 2000. *PSTA Research and Demonstration Project Phase 1 Summary Report*. February 1999 to March 2000.

## APPENDIX A

# Key Dates Summary

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Under contract with the District, Team Land Development (TLD) constructed four PSTA filed scale cells west of STA-2. Construction activities began in April 2000 on the first three Field Scale Cells. In November 2000, work began on a fourth peat-based Field Scale Cell. Monitoring activities began at the end of July 2001.

Dates of key activities conducted at the PSTA Field-Scale Cells are provided below for the study period of April 2000 to October 2001.

### April 2000

- **04/27/00:** Notice to proceed issued by the District to TLD.

### May 2000

- **05/02/00:** Mobilization of heavy equipment onsite.
- **05/10/00:** TLD determines that there is a large “muck hole” in the southern one-fifth of FSC-3, and estimates muck hole to be 3 to 4 feet deep.
- **05/11/00:** Removal of muck from floor of Field Scale Cell (FSC) -3 (excluding hole at southwest corner) and excavation of inflow canal are complete. Weir box locations are excavated to depth equal to that of inflow canal.
- **05/18/00:** District and CH2M HILL decide that the “hole” in FSC-3 should be filled in with caprock and that the height of perimeter levees needs to be raised by 1 foot.

### June 2000

- **06/14/00:** Muck removal in FSC-3 completed.
- **06/21/00:** Graded access roads around the site. Surveyors set benchmarks for the installation of the pipes and structures.
- **06/23/00:** Outflow weir structures set for FSC-2 and -3.
- **06/26/00:** Outflow weir structure set for FSC-1.
- **06/28/00:** Inflow weir structure set for FSC-3.

### July 2000

- **07/05/00:** FSC-2 inflow weir structure damaged; needed to be removed and repaired.
- **07/06/00:** Repair of FSC-2 inflow weir structure completed, and structure was reset in place. Filling of FSC-1 and -2 with cap rock completed.

- **07/20/00:** West perimeter and the seepage canal levees completed.
- **07/26/00:** Hole in FSC-3 filled, and grading of cell floor completed.

#### August 2000

- **08/04/00:** Hauling of fill for east perimeter levee completed.
- **08/08/00:** Hauling of fill for internal levees completed.
- **08/14/00:** Project trailer arrives onsite.
- **08/15/00:** All fill for levees onsite.
- **08/17/00:** Excavated culvert connections at inflow canal, seepage canal, and alternate water supply.
- **08/24/00:** All level roads graded and rolled. Completed grading of FSC-1 floor. Removed rock piles from FSC-2 to allow completion of cell floor grading.
- **08/31/00:** District met with TLD and declared project complete.

#### September 2000

- **09/06/00:** Pumps delivered onsite by Moving Water Industries (MWI). Inflow pumps for FSC-1, 2, and 3 set in place and started. CH2M HILL installed water level recorders at outflow weir boxes of FSC-1, 2, and 3. Walk through by District and CH2M HILL determines that floor of FSC- 1 requires additional grading to even out high and low spots. Installed water level recorders onto outflow boxes of FSC- 1, 2, and 3.
- **09/07/00:** Made cement bucket weights to use in FS cells to hold hose from inflow pumps in place.
- **09/08/00:** Installed water level recorders in the FS inflow and outflow canals. Installed PVC "T" diffusers on discharge pump hoses entering FS Cells. Inflow pump of FSC-2 shut down because of hydraulic fluid leakage.
- **09/15/00:** Increased weir heights in Field-Scale Cells to 3 ft.
- **09/18/00:** Final grading of FSC-1 and -2 floors and north entrance completed. Pumps repaired and re-started.
- **09/19/00:** Re-set weir height in Field-Scale Cells 2 ft. Determined that bringing in fill for FSC-4 from offsite is too expensive. Explored option of blasting a borrow pit area immediately west of site.
- **09/25/00:** Rain gauge installed at Field-Scale site.
- **09/27/00:** Significant amount of leakage observed through inflow (south) berm of Field-Scale cells.

#### October 2000

- **10/12/00:** Field-Scale cells measured for boardwalk placement. Met with Bagley Environmental and Planting Services to discuss *Eleocharis* planting. Decomposition study employing 1¼-inch PVC tubes, 15-cm length, begun at Porta-PSTA site.
- **10/14/00:** Second set of water collected at Field-Scale site for phosphorus background levels.
- **10/26/00:** FSC-4 pre-construction walk through to determine size and placement of borrow area.

#### November 2000

- **11/02/00:** Removal of muck from borrow area completed.
- **11/06/00:** Removal of muck from inflow canal extension to FSC-4 completed. Mowed internal area of FSC-4 and removed large Brazilian Pepper bushes.

#### December 2000

- **12/06/00:** Water level recorders removed from FS site to prevent damage they might incur from scheduled blasting (for fill in FSC-4). All pumps turned off for blasting event.
- **12/13/00:** Successful blasting of borrow area, insignificant amount of flying debris.
- **12/20/00:** Begin installing boardwalks in Field-Scale Cells. Meeting between District and CH2MHILL to finalize design of water supply pipe from STA 2 Cell 3 to inflow canal.

#### January 2001

- **01/03/01:** Completed removal of blasted material from borrow area, material determined to be of excellent construction quality.
- **01/24/01:** Completed re-filling and re-grading of inflow levee along FSC-1 and 2 to reduce leakage from cells.

#### February 2001

- **02/08/01:** Baseline sediment sampling at the Field-Scale Cells.
- **02/16/01:** All fill necessary to build FSC-4 levees in place.

#### March 2001

- **03/05/01:** Connected the agricultural ditch west of FSC-4 to the blasted borrow area.
- **03/06/01:** Completed boardwalk assembly at Field-Scale Cells.
- **03/07/01:** FSC-4 inflow weir box set in place.
- **03/09/01:** Grading of levees and discharge canal roads around FSC-4 completed.
- **03/12/01:** FSC-4 outflow weir box set in place.
- **03/13/01:** *Eleocharis cellulosa* planted in Field-Scale Cells (FSC) 1 and 2.

- **03/15/01:** Installed Agri-drain and 18-inch pipe at FSC-4 outflow.
- **03/21/01:** Complete widening of inflow canal around FSC-4 inflow weir box.
- **03/22/01:** Water level recorder moved from Field-Scale outflow canal to outflow weir box of FSC-4.
- **03/27/01:** Majority of FSC-4 work completed. Walk through determined that grates need to be added to top of inflow and outflow weir boxes, all roads around cell need a final grading and rolling, and a 2-foot extension to top of inflow weir box should be added.

#### April 2001

- **04/19/01:** Installed PVC "T" on discharge pump hoses for FS Cell 4 and FS Cell 3 out. Stop logs added to Agri-drains in FSC-1 and FSC-2 in attempt to reach target cell water depth of 1.0 ft.
- **04/24/01:** Installed additional 2-foot section to top of FSC-4 inflow weir box.
- **04/25/01:** All pumps at Field-Scale Cells shut down because of drought.
- **04/26/01:** Inventory equipment that will be used at Field-Scale office. Completed sealing of new top section to the original bottom section of FSC-4 inflow weir box.
- **04/27/01:** Pilings to support pipeline from STA-2 Cell 3 set into ground; pilings were too long and required trimming.

#### May 2001

- **05/09/01:** Western piling trimmed to proper length.
- **05/10/01:** Begin installation of water supply pipe from STA-2 Cell 3 to Field-Scale inflow canal.
- **05/11/01:** Completed cutting levees to place pipe for PSTA inflow canal. Completed back filling of inflow pipe.
- **05/14/01:** Pipe on STA-2 Cell 3 side completed; still need one more section of pipe on PSTA side.
- **05/30/01:** Water supply pipe from STA-2 Cell 3 to Field-Scale inflow canal completed.

#### June 2001

- **06/07/01:** GPS survey conducted at Field-Scale Cells by District.
- **06/14/01:** Agri-drain stop logs removed to allow flow through water supply pipe from STA-2 Cell 3 to Field-Scale inflow canal.
- **06/20/01:** Herbicide application to cattails in Field-Scale Cells.
- **06/21/01:** Survey conducted of STA-2 Cell 3 water supply pipe and Agri-drain elevations.
- **06/28/01:** All inflow pumps started at Field-Scale Cells.

- **06/29/01:** FSC-4 sprayed with herbicide by helicopter.

#### July 2001

- **07/05/01:** Survey conducted by District on structure elevations at Field-Scale Cells.
- **07/10/01:** Second application of herbicide on cattails at FSC-1, -2, and -3.
- **07/30/01:** ISCO samplers tested and deployed at Field-Scale Cells. Two stop logs removed from STA-2 Cell 3 water supply pipe Agri-drain.
- **07/31/01:** First 24-hour composite samples collected at FSC-1 and FSC-3 and inflow canal. Because of threat of hurricane, all samplers and meters secured in trailer at direction of the District.

#### August 2001

- **08/06/01:** Deployed and programmed ISCO samplers to collect 24-hour composite samples.
- **08/07/01:** Collected 24-hour composite samples at FSC-1 and FSC-3 and inflow canal.
- **08/09/01:** Collected 24-hour composite samples at FSC-1 and FSC-3 and inflow canal. Shut down pumps and removed stop logs to facilitate drying out of cells for well installation during the week of August 13, 2001. Added stop logs to STA-2 Cell 3 water supply pipe Agri-drain to stop flow into inflow canal.
- **08/14/01:** Begin installation of 10 groundwater wells Field-Scale Site.
- **08/17/01:** Complete well installation at FS Cells 1 and 3. Turned on pumps 1 and 3 and added stop logs to FSC-1 and FSC-3 outflow Agri-drains to set cell target water levels at 1 ft.
- **08/23/01:** Started pump at inflow of FSC-4.
- **08/24/01:** Removed all stop logs from STA-2 Cell water supply pipe Agri-drain.
- **08/25/01:** Deployed data logger with photosynthetically active radiation (PAR) and temperature probes in FSC-3.
- **08/28/01:** Monthly sampling event conducted at Field-Scale Cells.
- **08/30/01:** Collected 24-hour composite samples at FSC-1 and FSC-3 and inflow canal. Collected grab samples at FSC-2.

#### September 2001

- **09/04/01:** Collected 24-hour composite samples at FSC-2, FSC-3 and inflow canal. Grab sample collected at FSC-1 after composite sampler malfunctioned.
- **09/11/01:** PVC 'T' diffuser noted off end of discharge pump hose at inflow tube. Agri-drain at STA-2 Cell 3 water supply pipe cleared after being clogged with SAV.
- **09/25/01:** Groundwater samples collected for first time at Field-Scale Site wells.

- **09/26/01:** Installation of boardwalk extensions completed at all cells for groundwater sampling. PVC 'T' diffuser replaced on FSC-3 pump hose.
- **09/27/01:** Monthly sampling of groundwater wells and periphyton.

#### October 2001

- **10/03/01:** Pump at FSC-1 inflow replaced. Groundwater well sampling conducted. Three (7-inch) stoplogs removed from Agri-drain between STA-2 seepage canal and PSTA inflow canal. Two (5 inch) stoplogs remain.
- **10/04/01:** Pump at FSC-4 increased from 1300 to 1600 rpm to achieve outflow.
- **10/09/01:** Sediment traps deployed in all cells.
- **10/16/01:** One (7-inch) stoplog added to Agri-drain from STA-2 seepage canal to PSTA inflow canal to stop backflow of water into seepage canal. Stakes placed in Field-Scale Cells for field flow measurements ('orange method').
- **10/23/01:** AMJ onsite to begin installation of flow meters.
- **10/24/01:** PAR bulb cleaned off. Periphyton sampling for quarterly event.

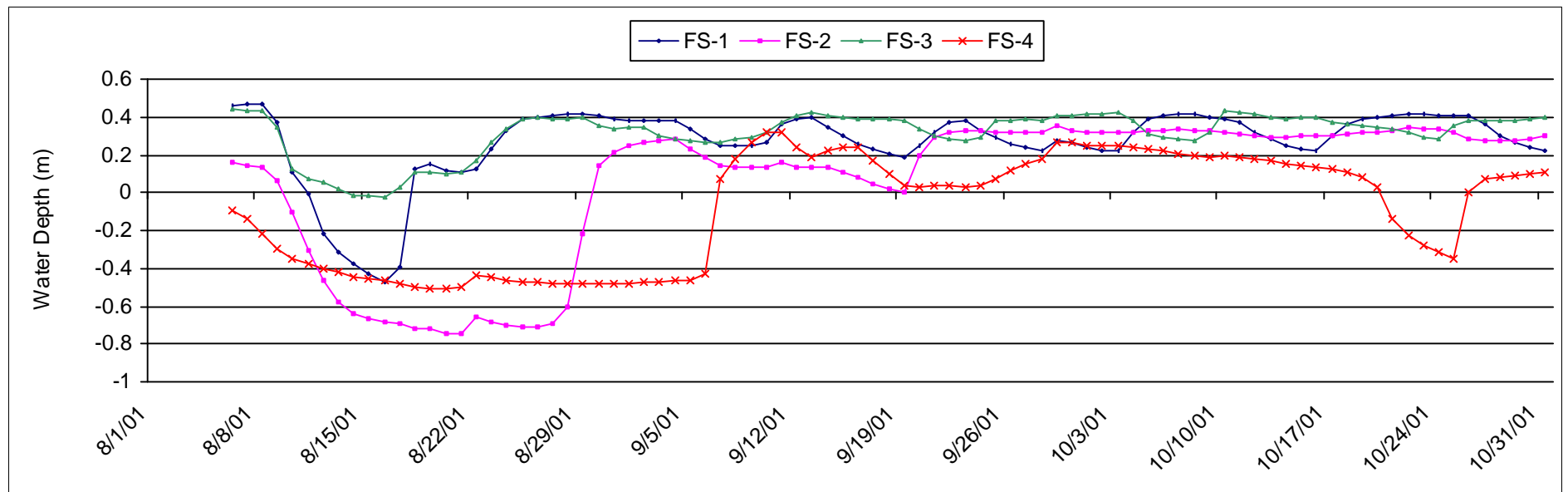
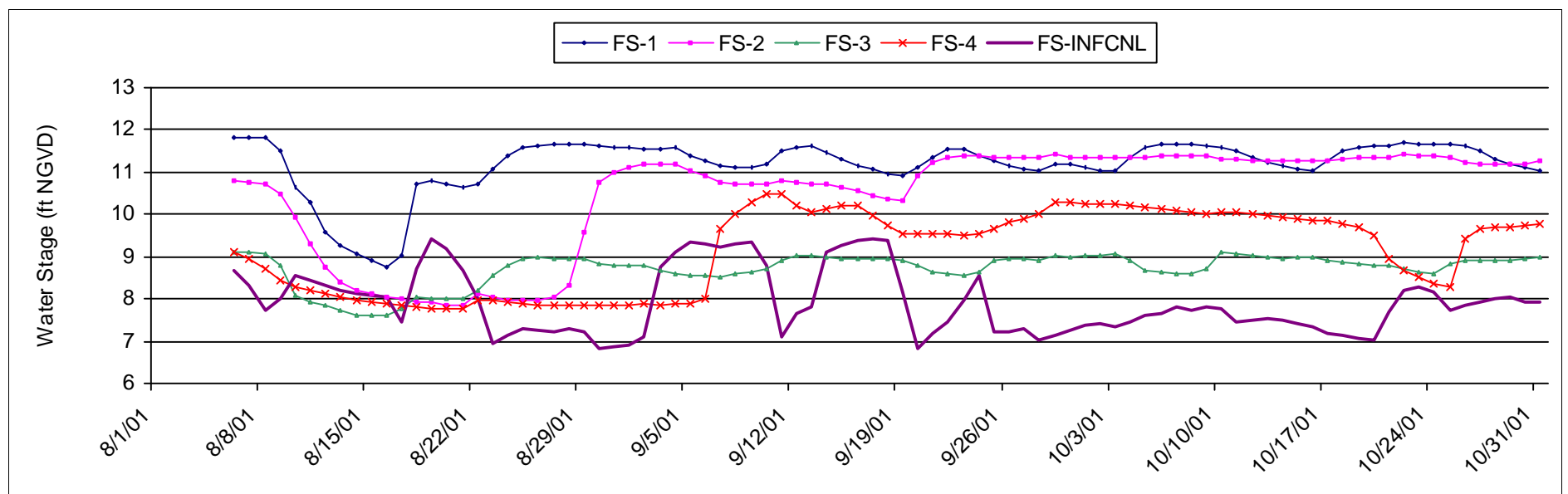
#### November 2001

- **11/1/01:** Photos taken of Field-Scale Cells. Tropical storm warning; ISCO samplers, sondes, and Infinities water level recorders removed.
- **11/2/01:** Staff gauges installed in Field-Scale Cells.
- **11/6/01:** ISCO samplers, sondes, and Infinities re-deployed.
- **11/29/01:** Pumps shut down and five (7 inch) stoplogs added to STA-2 Cell 3 water supply pipe Agridrain to dry cells for vegetation maintenance. MWI onsite to replace discharge hose on FSC 3 pump; leak noted on November 13, 2001. Monthly sampling event.

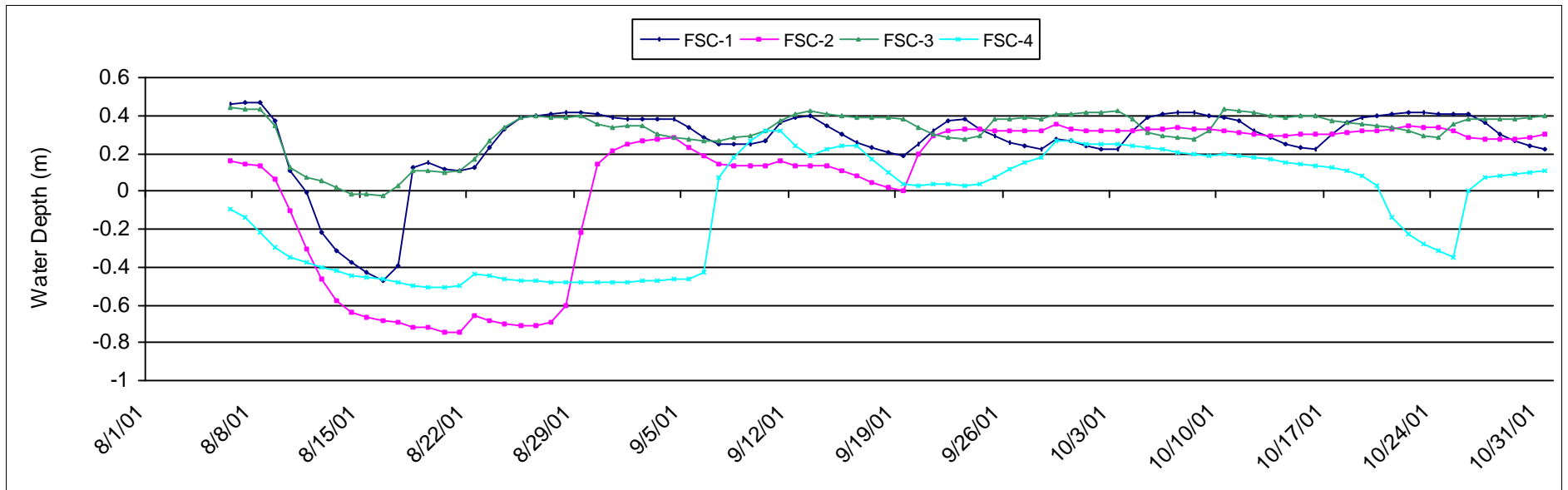
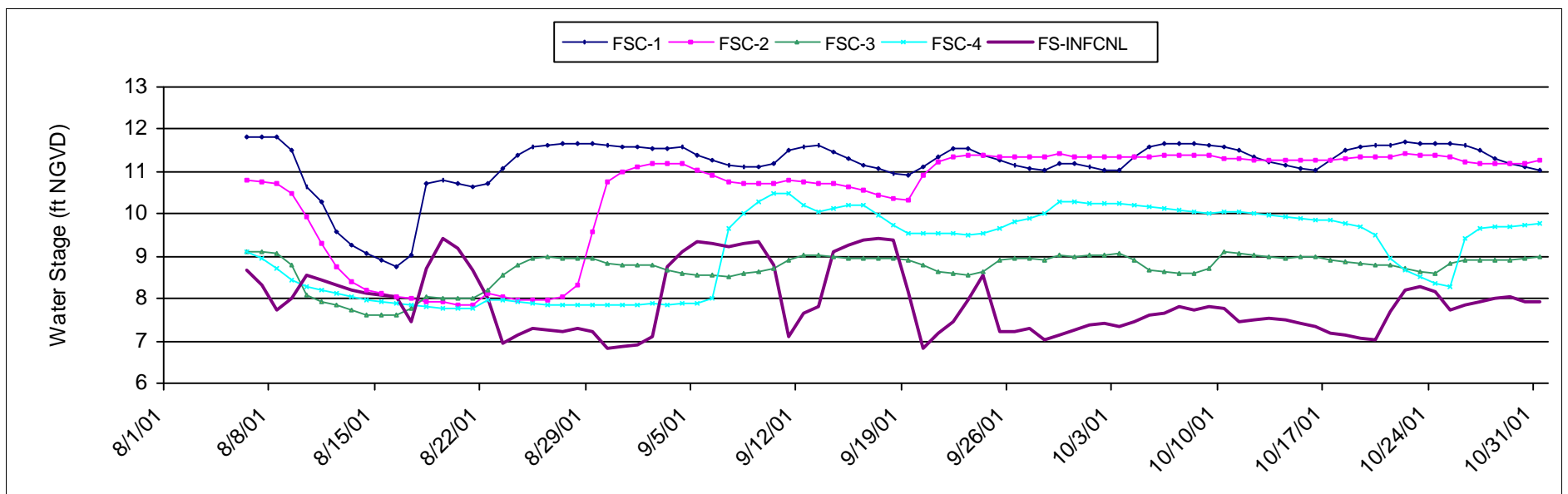
#### December 2001

- **12/5/01:** Surveyors onsite to perform elevation survey. Survey completed with the exception of tying into an existing benchmark.
- **12/10/01:** Removed all stoplogs (five 7 inch) from STA-2 Cell 3 water supply pipe Agridrain. Removed one (7 inch) and one (5 inch) stoplog from STA-2 Seepage Canal Agridrain.
- **12/13/01:** One (5 inch) stoplog added to FS Cell 1 Agridrain.
- **12/18/01:** Monthly sampling event.

## PSTA Research and Demonstration Project Phase 3 Field Scale PSTAs



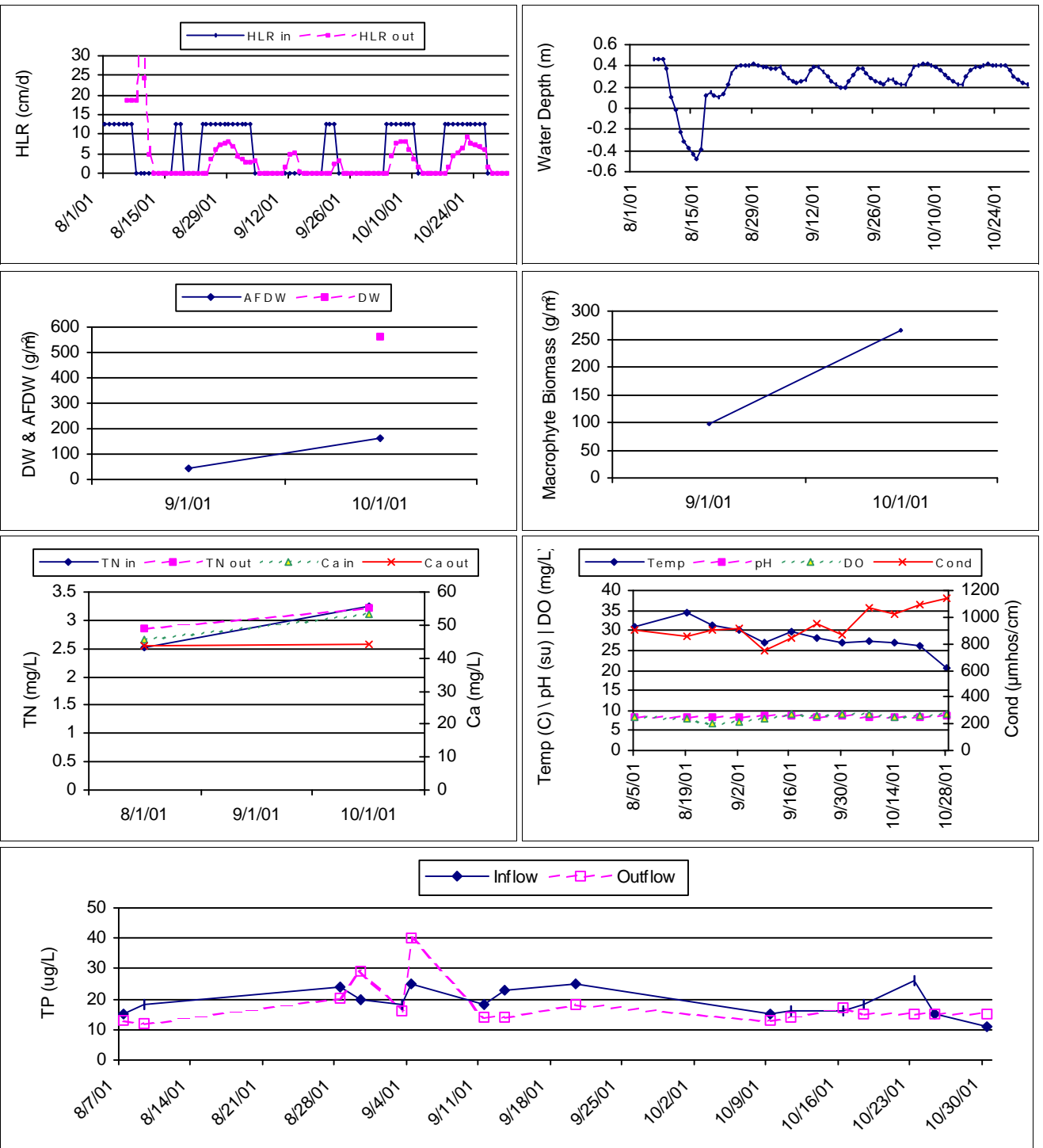
## PSTA Research and Demonstration Project Phase 3 Field Scale PSTAs



# PSTA Research and Demonstration Project Phase 3

## Field Scale PSTAs

<b>Treatment:</b> FSC-1	<b>Period:</b> 8/1/2001 - 10/31/2001
<b>Cell Size:</b> 66 x 315 m (2.08 ha)	<b>Soil:</b> Limerock fill over peat



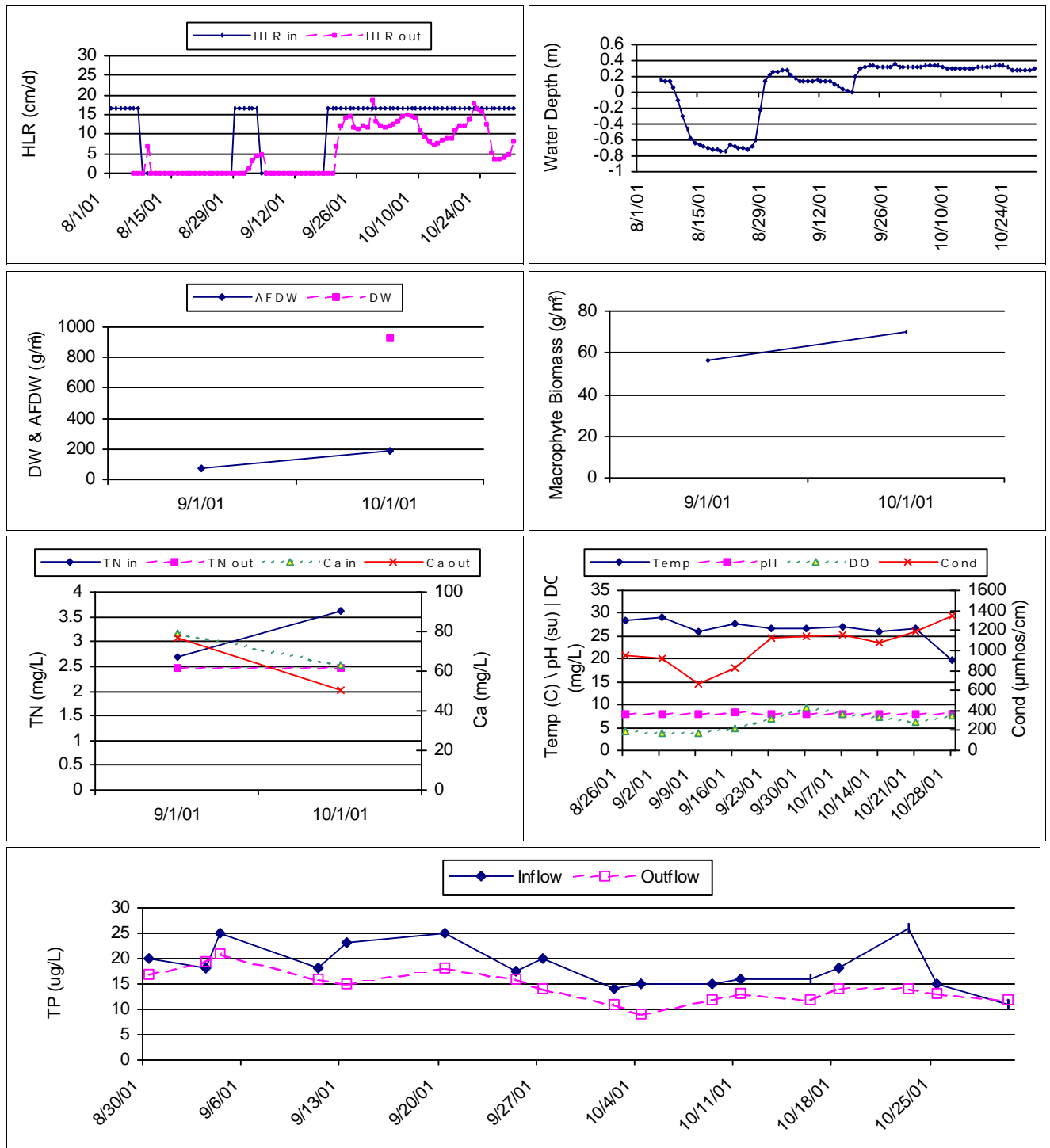
### Summary for Period

Cell	Avg HLR (cm/d)	Depth (m)	TP in (ug/L)	TP out (ug/L)	k <sub>1</sub> (m/yr)
FS-1	4.56	0.26	19	18	1.3

# PSTA Research and Demonstration Project Phase 3

## Field Scale PSTAs

<b>Treatment:</b> FSC-2	<b>Period:</b> 8/1/2001 - 10/31/2001
<b>Cell Size:</b> 22 x 945 m (2.08 ha)	<b>Soil:</b> Limerock fill over peat



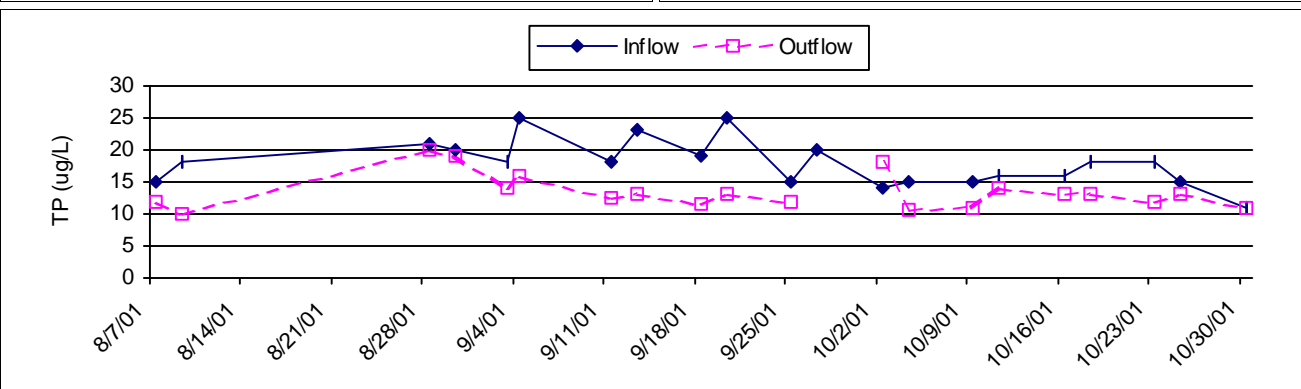
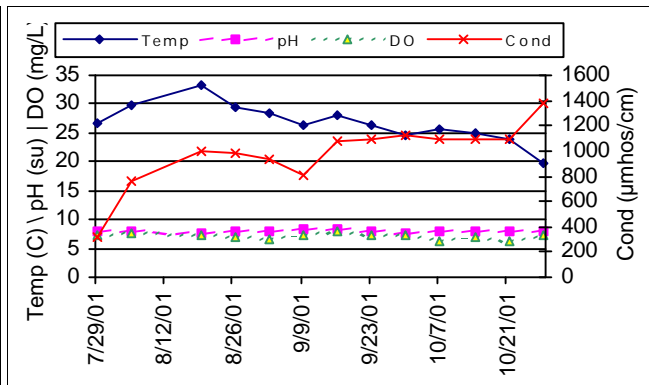
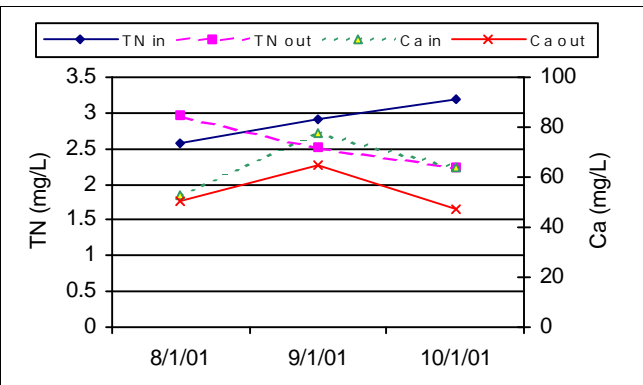
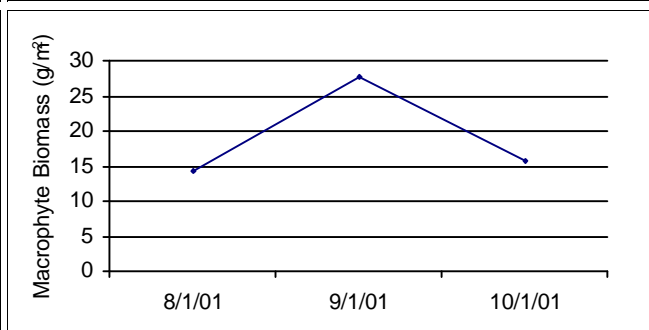
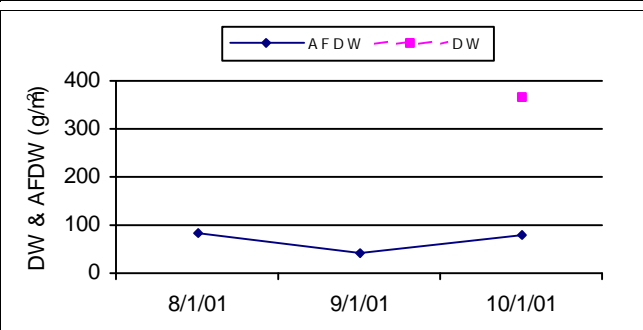
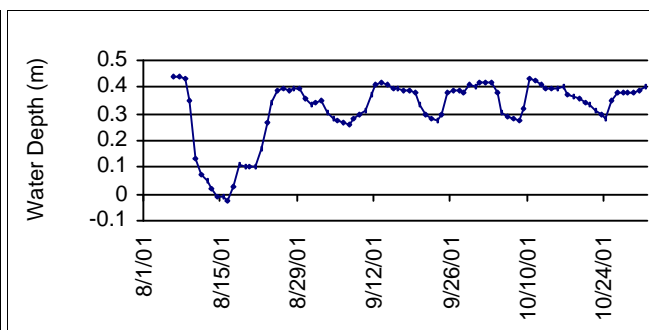
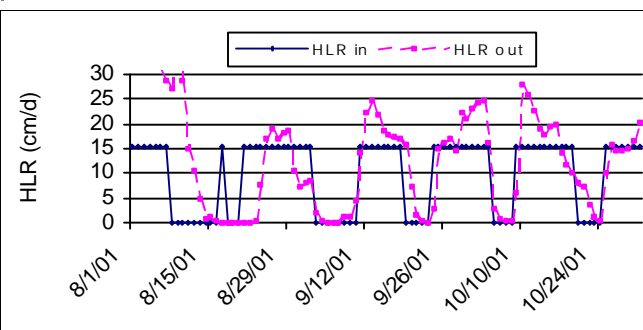
### Summary for Period

Cell	Avg HLR (cm/d)	Depth (m)	TP in (ug/L)	TP out (ug/L)	k <sub>1</sub> (m/yr)
FS-2	7.83	0.05	18	15	6.8

# PSTA Research and Demonstration Project Phase 3

## Field Scale PSTAs

<b>Treatment:</b> FSC-3	<b>Period:</b> 8/1/2001 - 10/31/2001
<b>Cell Size:</b> 66 x 315 m (2.08 ha)	<b>Soil:</b> Limestone caprock



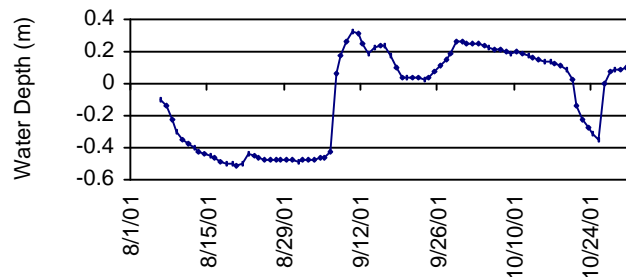
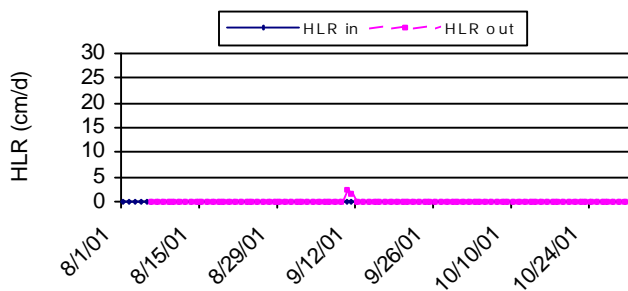
### Summary for Period

Cell	Avg HLR (cm/d)	Depth (m)	TP in (ug/L)	TP out (ug/L)	$k_1$ (m/yr)
FS-3	10.88	0.31	18	13	11.3

# PSTA Research and Demonstration Project Phase 3

## Field Scale PSTAs

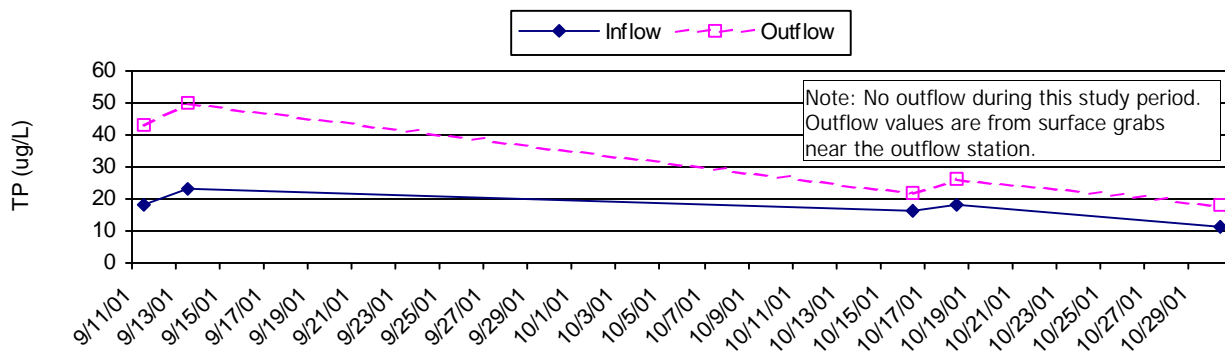
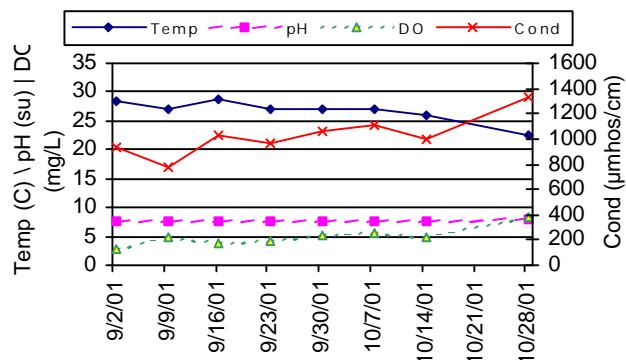
<b>Treatment:</b> FSC-4	<b>Period:</b> 8/1/2001 - 10/31/2001	
<b>Cell Size:</b> 66 x 315 m (2.08 ha)	<b>Soil:</b> Peat	



Dry Weight and Ash-Free Dry Weight data are not available for this study period

Macrophyte Biomass data are not available for this study period

Total Nitrogen and Calcium data are not available for this study period



### Summary for Period

Cell	Avg HLR (cm/d)	Depth (m)	TP in (ug/L)	TP out (ug/L)	k <sub>1</sub> (m/yr)
FS-4	0.02	-0.08	17	32	na

Note: No outflow during this study period

# Appendix C-1

Field Scale Cell Average Algal Cell Counts (#cells/m<sup>2</sup> x 10<sup>6</sup>), October 2001

Organism Code	Division Code	Organism	Field Scale Cells		
			FSC-1	FSC-2	FSC-3
APHN FLO	01	APHANIZOMENON FLOS-AQUAE		201613	
APHA STA	01	APHANOTHECE STAGNINA		129032	64516
CHR DIS	01	CHROOCOCCUS DISPERSUS	32258		
CHR MINI	01	CHROOCOCCUS MINIMUS	338710	387097	637097
CHR MIN	01	CHROOCOCCUS MINUTUS	16129		16129
CHR PRE	01	CHROOCOCCUS PRESCOTTII	129032		
CHR TUR	01	CHROOCOCCUS TURGIDUS	16129	0	0
COE PUS	01	COELOMORON PUSILLUM	0	225806	0
G GLO	01	GLOEOCAPSA SP	0	48387	0
JAA ANG	01	JAAGINEMA ANGUSTISSIMUM	693548	645161	967742
LEP LAG	01	LEPTOLYNGBYA LAGERHEIMII	838710	306452	0
MER TEN	01	MERISMOPEdia TENUISSIMA	209677	0	0
PHO FOR	01	PHORMIDIUM FORMOSUM	709677	0	0
PHO WIL	01	PHORMIDIUM WILLEI?	0	0	564516
PLA SUB	01	PLANKTOLYNGBYA SUBTILIS	1274194	483871	193548
PSE LIM	01	PSEUDANABAENA LIMNETICA	1209677	3346774	1612903
PSE MON	01	PSEUDANABAENA MONILIFORMIS	193548	96774	129032
SCH ARE	01	SCHIZOTHRIX ARENARIA?	0	1612903	0
G SCY	01	SCYTONEMA SP?	435484	0	0
SPI SUB	01	SPIRULINA SUBSALSA	0	8065	8065
G SYNE	01	SYNECHOCOCCUS SP	80645	0	185484
ANK NAN	03	ANKISTRODESMUS NANNOSELENE	0	8065	0
ANK SPI	03	ANKISTRODESMUS SPIRALIS	8065	0	0
G CHLA	03	CHLAMYDOMONAS SP	8065	0	0
DIC PUL	03	DICTYOSPHAERIUM PULCHELLUM	0	0	32258
OOC SOL	03	OOCYSTIS SOLITARIA	8065	0	0
SCE BIJ	03	SCENEDESMUS BIJUGA	16129	32258	24194
SCE BIJ AL	03	SCENEDESMUS BIJUGA V ALTERNANS	32258	0	0
SCE DEN	03	SCENEDESMUS DENTICULATUS	0	0	16129
SCE QUA	03	SCENEDESMUS QUADRICAUDA	0	16129	0
G SPI	03	SPIROGYRA SP	0	16129	0
TET MIN	03	TETRAEDRON MINIMUM	0	0	8065
TET TRI	03	TETRAEDRON TRIGONUM	0	8065	0
ACHN MIN	04	ACHNANTHIDIUM MINUTISSIMUM	8065	8065	8065
BRA VIT	04	BRACHYSIRA VITREA	0	88710	48387
CYM MIC	04	CYMBELLA MICROCEPHALA	0	32258	8065
DIP OBL	04	DIPLONEIS OBLONGELLA	0	0	8065
DIP OVA	04	DIPLONEIS OVALIS	8065	8065	0
ENC EVE	04	ENCYONEMA EVERGLADIANUM	16129	32258	32258
FRA SYN	04	FRAGILARIA SYNEGROTESCA	0	16129	0
GOM PAR	04	GOMPHONEMA PARVULUM	8065	16129	0
MAS SMI LA	04	MASTOGLOIA SMITHII V LACUSTRIS	0	8065	8065
NAV CRY	04	NAVICULA CRYPTOCEPHALA	8065	24194	0
NAV CRYP	04	NAVICULA CRYPTOTENELLA	0	8065	0
NAV POD	04	NAVICULA PODZORSKII	0	8065	0
NIT PAL	04	NITZSCHIA PALEA	8065	0	0
NIT PALE	04	NITZSCHIA PALEACEA	0	8065	0
NIT PALF	04	NITZSCHIA PALEAFORMIS	16129	40323	0
NIT SEM	04	NITZSCHIA SEMIROBUSTA	16129	16129	8065
G NIT SM	04	NITZSCHIA SP (SMALL)	8065	40323	8065

Note: Periphyton samples were not collected from FSC-4 in October 2001.

## Appendix C-2

Field Scale Cell Average Algal Biovolume Data (cm<sup>3</sup>/m<sup>2</sup>), October 2001

Organism Code	Division Code	Organism	Field Scale Cells		
			FSC-1	FSC-2	FSC-3
APHN FLO	01	APHANIZOMENON FLOS-AQUAE	0	4435	0
APHA STA	01	APHANOTHECE STAGNINA	0	3097	1548
CHR DIS	01	CHROOCOCCUS DISPERSUS	452	0	0
CHR MINI	01	CHROOCOCCUS MINIMUS	1355	1548	2548
CHR MIN	01	CHROOCOCCUS MINUTUS	177	0	177
CHR PRE	01	CHROOCOCCUS PRESCOTTII	20903	0	0
CHR TUR	01	CHROOCOCCUS TURGIDUS	4323	0	0
COE PUS	01	COELOMORON PUSILLUM	0	1355	0
G GLO	01	GLOEOCAPSA SP	0	194	0
JAA ANG	01	JAAGINEMA ANGUSTISSIMUM	1387	1290	1935
LEP LAG	01	LEPTOLYNGBYA LAGERHEIMII	5032	1839	0
MER TEN	01	MERISMOPEDIA TENUISSIMA	210	0	0
PHO FOR	01	PHORMIDIUM FORMOSUM	56064	0	0
PHO WIL	01	PHORMIDIUM WILLEI?	0	0	11855
PLA SUB	01	PLANKTOLYNGBYA SUBTILIS	22935	8710	3484
PSE LIM	01	PSEUDANABAENA LIMNETICA	8468	23427	11290
PSE MON	01	PSEUDANABAENA MONILIFORMIS	2516	1258	1677
SCH ARE	01	SCHIZOTHRIX ARENARIA?	0	20968	0
G SCY	01	SCYTONEMA SP?	603145	0	0
SPI SUB	01	SPIRULINA SUBSALSA	0	508	508
G SYNE	01	SYNECHOCOCCUS SP	5161	0	11871
ANK NAN	03	ANKISTRODESMUS NANNOSELENE	0	32	0
ANK SPI	03	ANKISTRODESMUS SPIRALIS	97	0	0
G CHLA	03	CHLAMYDOMONAS SP	2161	0	0
DIC PUL	03	DICTYOSPHAERIUM PULCHELLUM	0	0	452
OOC SOL	03	OOCYSTIS SOLITARIA	10944	0	0
SCE BIJ	03	SCENEDESMUS BIJUGA	161	323	242
SCE BIJ AL	03	SCENEDESMUS BIJUGA V ALTERNANS	1032	0	0
SCE DEN	03	SCENEDESMUS DENTICULATUS	0	0	3339
SCE QUA	03	SCENEDESMUS QUADRICAUDA	0	1645	0
G SPI	03	SPIROGYRA SP	0	1613868	0
TET MIN	03	TETRAEDRON MINIMUM	0	0	371
TET TRI	03	TETRAEDRON TRIGONUM	0	7847	0
ACHN MIN	04	ACHNANTHIDIUM MINUTISSIMUM	1129	1129	1129
BRA VIT	04	BRACHYSIRA VITREA	0	40629	22161
CYM MIC	04	CYMBELLA MICROCEPHALA	0	5484	1371
DIP OBL	04	DIPLONEIS OBLONGELLA	0	0	2710
DIP OVA	04	DIPLONEIS OVALIS	3250	3250	0
ENC EVE	04	ENCYONEMA EVERGLADIANUM	3032	6065	6065
FRA SYN	04	FRAGILARIA SYNEGROTESCA	0	17290	0
GOM PAR	04	GOMPHONEMA PARVULUM	14404	28806	0
MAS SMI LA	04	MASTOGLOIA SMITHII V LACUSTRIS	0	12969	12969
NAV CRY	04	NAVICULA CRYPTOCEPHALA	3420	10258	0
NAV CRYP	04	NAVICULA CRYPTOTENELLA	0	5984	0
NAV POD	04	NAVICULA PODZORSKII	0	17783	0
NIT PAL	04	NITZSCHIA PALEA	4234	0	0
NIT PALE	04	NITZSCHIA PALEACEA	0	508	0
NIT PALF	04	NITZSCHIA PALEAFORMIS	13774	34436	0
NIT SEM	04	NITZSCHIA SEMIROBUSTA	9484	9484	4742
G NIT SM	04	NITZSCHIA SP (SMALL)	855	4274	855

Note: Periphyton samples were not collected from FSC-4 in October 2001.